MAY 8 - 1924

VOL-XIV NO-5

THE JOURNAL OF THE SOCIETY OF AUTOMOTIVE ENGINEERS

MAY 1924

SOCIETY OF AUTOMOTIVE ENGINEERS INC.
29 WEST 39TH STREET NEW YORK

Preventing viciousness *versus* Permitting it and then Stopping it

GENERALLY it takes a long time to get recognition on something as radical as Stabilation.

In attempting to control spring rebound it has been the custom for years to check the rebound at the tail-end of the movement —after the movement has been permitted to get viciously under way. First we had the hanging type of jump-strap, and later, many forms of the wind-up type.

Stabilation has about-faced and gone in an entirely opposite direction. Stabilation is accomplished not by a tail-end *stopping* of the rebound movement, but by the application of a brake or drag *throughout* the movement—a drag which is heavy at the *start* of the movement, when the spring is heavily compressed and its rebound force is vicious, and which tapers off as the spring returns to its normal state. With Stabilation, therefore, it isn't a case of *stopping* a vicious movement, it's a case of *not permitting* viciousness.

Jump-strapping and Stabilation are thus precisely opposite in both principle and effect. And the logic and correctness of Stabilation has been proved beyond question by the almost instant recognition it has received.

JOHN WARREN WATSON COMPANY
Twenty-fourth and Locust Streets
PHILADELPHIA

WATSON
STABILATORS
Change the Whole Nature of Your Car

THE JOURNAL OF THE SOCIETY OF AUTOMOTIVE ENGINEERS

Vol. XIV May, 1924 No. 5

Chronicle and Comment

The Employment Service

THE attention of general managers and others who are responsible for the employment of technically trained men, including engineers and managers of production, service and sales departments, is especially directed to the notice on p. 28 in the advertising section of this issue, referring to the S.A.E. Employment Service.

Through this service, the Society has placed 63 members in responsible engineering and managerial positions in the last 6 months.

Many letters commending the service have been received from the members and the companies.

To Improve Automotive Service

WHAT promises to be one of the most important and influential gatherings ever devoted to reducing the cost and improving the quality of automobile service will be held at Detroit this month. All activities are centered in the General Motors Building during the period May 19 to 22. A program and announcement of the National Automotive Service Convention and Automotive Maintenance Equipment Show has been mailed to all the members. While the National Automobile Chamber of Commerce is responsible for these two important events, the Society has cooperated with other organizations in the arrangements. For this reason our members may feel privileged to attend any or all of the meetings and to visit the interesting and educational exhibits at the Show.

President Crane, Past-President Alden and other members of the Society will read papers. Some of the titles of interest to the engineer are as follows:

How To Fit Pistons and Bearings Properly
Proper Adjustment of Rear-Axle Gears and Bearings
Adjustment of Brakes
How the Service Man Can Cooperate with the Engineer
The Effect of Poor Lubrication

All meetings will be held in the afternoon starting at 2 o'clock. The Show will be open during the morning and evening. It will house exhibits of all the latest equipment made especially for the repairing of automotive vehicles in service-stations and garages. Engine-repair stands, cylinder reboring and regrinding equipment, valve-grinding devices, special wrenches, chassis cranes and all manner of other garage accessories will be on view.

Safety Code on Brakes and Brake Testing

REALIZING the need for a dependable basis for brake regulations, the American Engineering Standards Committee has asked the American Automobile Association, the Bureau of Standards and the Society of Automotive Engineers to act as joint sponsors for a safety code on automobile brakes and brake testing. Such a code would be designed to fulfil the urgent need for a standard specification applicable to present-day conditions and susceptible of future modification.

It is apparent from a study of both state and municipal regulations that no uniformity of requirements now exists. Furthermore, many of the present ordinances are entirely inadequate, and others are perhaps unfair. In all probability more ordinances relative to brake performance and inspection will be passed by states and municipalities; and, if a satisfactory code can be formulated, it should accomplish much toward unifying laws that are being passed and toward obtaining *not more laws but more reasonable ones.*

At an informal conference of the sponsors, held on April 18, important matters relating to the requirements of a code and the investigation necessary for formulating a standard specification were discussed. It is hoped that a sectional committee may soon be organized to carry on actively the work involved in this project.

Concurrent-Lock Standard Adopted

ON Jan. 1, 1925, a new standard developed by the Underwriters' Laboratories for a concurrent automobile lock will become effective. This standard specifies that the ignition switch shall operate concurrently with the locking device so that the locking of the transmission, steering-wheel or whatever anti-theft lock is used shall break the ignition circuit.

The reason for the new standard is that the Underwriters' Laboratories has determined that, although many cars are equipped with anti-theft locks, these are not used in many instances, statistics showing that the cars stolen are not those in which locking devices have

been tampered with, but those that have been left unlocked. The new standard consequently requires that the anti-theft lock shall be constructed so that it must be locked to open the ignition circuit or unlocked to complete the circuit. The standard does not require that the key shall be removed to break the ignition circuit, but it is believed that the elimination of one key and locking device will influence the automobile owner to take the key with him when he leaves the car.

No greater discount in theft-insurance premiums will be allowed at this time for the concurrent or coincidental lock and it is understood that no action in this connection will be taken without several months' notice to that effect.

Rail-Cars Are Here to Stay

JUDGING from reports made by railroad engineers at a recent meeting of the Midwest Section in Chicago, the motor rail-car has come to stay in the field of rail transportation. It cannot be said that the ultimate type of car has been developed to suit all classes of service, but several satisfactory units are on the market which have proved their worth in actual operation. Particularly interesting are the constructive criticisms of one railroad engineer which are based on several years' experience in the operation of rail-cars. These are given on p. 475. It is clearly evident from these criticisms that the rail-car of the future will be the joint product of the railroad engineer and the automotive engineer. Either one working alone will be seriously handicapped. While the resultant cooperative design will be a compromise, it is hoped that the railroad tendency toward heavy weights will be modified by the automotive engineer's knowledge of alloy-steels and weight-reduction methods.

One interesting point is raised in the paper in question; it is recommended that all screw threads and utility parts be made according to U. S. Standards. The disadvantage of injecting a new standard into railroad service is recognized, but there are many sound engineering reasons for the use of S.A.E. standards for rail-cars. The final decision should not be made without very careful deliberation.

The Summer Meeting

IT will not be long before the curtain rises on the Summer Meeting of the Society at Spring Lake, N. J. As already announced, this popular event is scheduled to be held from June 24 to 27 at this attractive Atlantic coast resort. Last year's experience showed Spring Lake to be suited ideally to the demands of a meeting such as the Society's summer conclave. Hotel and meeting facilities are modern, high-class and adequate. Golf, tennis, swimming, trap-shooting and many other branches of sport can be enjoyed.

Four major topics will be treated in the technical sessions; these are crankcase-oil dilution, air-cleaners, riding-quality and new forms of automobile transmissions. Many interesting exhibitions and demonstrations are being arranged to fit in with the program of papers. Further details of the professional activities are given on p. 482.

Application blanks for hotel rooms will reach all the members in the early part of May. These should be forwarded to the offices of the Society in New York City without delay. Reduced railroad fares will be available between principal automotive centers and Spring Lake. Special train service will transport contingents from the Middle West to the meeting and return them in comfort after its close. Arrange your work schedule at this early date so that it will be possible for you to leave the factory from June 24 to 27 and attend the Summer Meeting, preferably with your wife and family.

Inspection and the Engineer

A TENDENCY toward better workmanship and closer tolerances has been apparent in the automotive industry ever since the war. Even in cars in the moderate-price class, it is not uncommon to find limits carried into the fourth decimal place. Dimensional standards are not the only ones affected. Similar progress is being made toward the exaction of finer surface finish, more uniform weights and greater precision of balance; material specifications are being more strictly adhered to. Truly, "go" and "no-go" are getting nearer and nearer together in all phases of inspection.

The logical result of this movement has been a demand for improved means of inspection and the placing of inspection itself on a true engineering plane. A recent meeting of the Detroit Section, reported on p. 472 of this issue of THE JOURNAL, was probably the first of its kind where inspectors met together and discussed their problems. Anyone hearing the papers, the questions and the discussion at this meeting soon appreciated the broadening technical aspect of this branch of the automotive industry. Among the questions alone, enough subjects for a dozen valuable papers were presented. The Society will follow through this inaugural effort and endeavor to encourage papers and meetings in the inspection field. These will be of vital interest to the engineer who is always anxious to have his drawings interpreted accurately in the finished piece. The production man will be interested because he must build to meet the growing tendency toward precision and will have to keep informed on the advances made in inspection methods.

The Tractor Engineer's Responsibility

FARM tractors must be simplified, reduced in cost and increased in utility. It is the engineer's responsibility to achieve these ends if the tractor industry is to enjoy even moderate activity in the immediate future. These were the key-notes struck at the recent Tractor Meeting of the Society in Chicago. The buying power of the American farmer is at low ebb. This makes him a cautious purchaser; not only must prices be low to meet his purse, but he also insists that any new equipment give promise of making tangible and material reductions in his farming costs before he will buy it. Single-purpose tractors will not do; the farm market will lie dormant until the tractor engineers sense the full force of this statement and exercise their ingenuity in perfecting combinations of motive-power and implements which more nearly supplant the horse. Further than that, these combinations should do the work better than the horse can do it, in less time and at a lower overall cost.

This is a large bill to fill. There will be skeptics who will opine that it cannot be done, but the fact remains that the present economic condition of the farmer demands that just this be done. Cyrus McCormick, Jr., made a very frank commentary on the situation in his talk at the Tractor Luncheon. His remarks are reviewed on p. 486. He implied that the tractor engineer must lead the industry out of its present dormant state. While Mr. McCormick's statements may not find favor among the professional optimists, they will certainly set en-

gineers to thinking. One cannot refrain from remarking that here again we find that all-important fundamental of successful business cropping up; "fit the goods to the market."

Judging from the discussion at the morning session of the Tractor Meeting, which is reported on p. 483, tractors are finding an active market in the industrial field. It might be argued that industry is prosperous and can afford to buy tractors, but this may not be the primary justification for the demand. Is it not more likely that the tractor is used in industry because it does things that animals cannot do and does them efficiently and cheaply?

Membership Increase Is Gratifying

THE immediate response by very many members to a postcard recently sent out with a *Meetings Bulletin*, requesting the names of men eligible for membership, is greatly appreciated by the Membership Committee. Two hundred and twenty-eight names of high-grade men have been received up to the present time and additional names are being received in each mail. Applications for membership are being received at double the former rate.

President H. M. Crane, in addressing the 1924 Annual Dinner in New York, said:

> No organization in the industry is today so big that it can do without the Society. I have talked to many men who have been active in Society affairs and they are unanimous in saying that they have invariably got infinitely more from the Society than they were ever able to give to the Society.

The Membership Committee feels that every high-grade technical man in the industry can obtain some benefit through membership in the Society. The active interest of a chief executive in the work of the Society stimulates the interest of the other key men of his organization. He can also benefit personally through the Society's activities in the production field. The production manager or service manager who holds membership in the Society will be kept familiar with the problems involved in the manufacture or service of a new development before it reaches the manufacturing or service department. The operators of fleets of trucks, buses, taxicabs, motor rail-cars, and other automotive transportation media have an important place in the membership of the Society. In addition to their engineering problems and the proper maintenance of their equipment they have the collateral problem of properly adapting equipment to special purposes with due economical and efficient operation. The purchasing agent can materially benefit his company through Society membership. The economical adoption and application of various products, such as steels, paints, leather, wood and other supplies, parts or accessories, are usual topics of discussion at meetings of the Society.

Members will perform a service to the Society and to their non-member friends by informing the office of the Society of men who could profit by affiliation with this engineering body. If you know of executives, engineers, factory men or others in your organization who should join the Society, forward their names and an effort will be made to interest them in membership.

The Stop-Gap Against Inaccessibility

HOW often we hear the remark "If the chief engineer were forced to repair cars of his own design, inaccessible adjustments and parts would be reduced to a minimum." Perfectly true, no doubt, but where lies the real cause of negligence implied by this statement? Certainly nobody with an appreciation of a chief engineer's responsibility and the value of his time would expect him to don overalls daily and assume the role of a grimy mechanic. Clearly, the real responsibility for passing inaccessible constructions on to the public lies elsewhere. It must be placed on the shoulders of the man who is in charge of chassis testing work in the experimental shops.

The foreman in charge of the testing of experimental models is an important personage, as are his mechanics. The qualifications for this important responsibility demand that these men have imagination as well as mechanical skill. As each adjustment or repair is made they must visualize how the owner-driver will react when he undertakes the same job. Too often mechanics who are accustomed to a greasy environment pass lightly over a task that would ruffle the spirits of even the most liberal-minded owner. Adjustments that require a combination of special tools and physical acrobatics are not reported as troublesome and they are passed on to the car-owner without the designer's knowledge.

What is the remedy? First of all, extreme care should be taken by every chief engineer in selecting the mechanics for the experimental garage. They must be more than mere wrench handlers; an appreciation of the owner's viewpoint and a recognition that they stand guard against bad design in the last-line trenches should be theirs. The engineering division of the Air Service has long appreciated and capitalized good test pilots as a safeguard against unsatisfactory airplane designs. The other branches of the industry should show the same care in selecting test-car drivers and experimental shop mechanics.

Another method worthy of greater application is the performance on a completed experimental model of the 50 repair and maintenance operations made most frequently in the average service-station. This procedure should be under the careful observation of an engineering department representative. Among such operations would be valve-grinding, carbon-cleaning, brake-relining, engine-tuning, fan-belt replacement and the like. Not only should these operations be timed but they should also be fully analyzed. Commercial foresight suggests that the cost in labor and material be compared with the prices charged by competing companies for similar operations on cars of the same class.

Comparison of flat-rate charges will reveal design points needing alteration and refinement. No matter how ingenious a particular installation may appear in an engineering sense it is not good design if a competitor accomplishes the same purpose with a layout that performs satisfactorily and can be repaired at a lower cost. This repair-cost comparison will do much to take unnecessary frills out of design.

More study should be given the trouble-shooting methods of the experimental garage. True, many faults are found and corrected which interfere with the proper functioning of the powerplant or the chassis, but this is only half of the job. When the experimental testing department puts its stamp of approval on a design it should mean that this particular car not only operates properly, but that it can be repaired and maintained cheaply. The experimental garage mechanic and the foreman should be the judges, and money spent to secure conscientious workmen with some appreciation of the car-owner's viewpoint will eliminate much of the lurid correspondence that travels between the dealer and the factory.

MEETINGS OF THE SOCIETY

FLAT-RATES FORCING ACCESSIBILITY

Washington Speaker Cites Unwarranted Difference Between Rates for Similar Cars

A. W. S. HERRINGTON

The public has definitely notified the automobile designer that it is interested in maintenance costs and that in the future it will analyze them even more carefully than in the past. The limelight of the flat-rate system is being focused squarely upon this one point, accessibility. These opinions were expressed by A. W. S. Herrington who addressed the Washington Section on April 4 on the effect of accessibility upon automobile maintenance cost. Back on the drafting board when the first layouts of a new design are made, maintenance charges are inserted or eliminated, made expensive or inexpensive, said Mr. Herrington. Two ounces of horse sense will save hundreds of thousands of dollars for the users of that automobile.

One of the most frequent maintenance operations is that known as carbon removal, grinding of valves and tuning the engine. A list of flat-rate charges for this work on five well-known eight-cylinder automobiles, each of approximately 350-cu. in. displacement follows:

Car	Price
A	$14.00
B	18.40
C	25.00
D	37.50
E	42.50

All of these automobiles are in approximately the same price class. They represent the pick of our high-grade cars. The pistons in these engines are all within plus and minus ⅛ in. of the same diameter. They all have two valves per cylinder and the valves are all nearly the same size. They will all require this maintenance work in the same amount of mileage. These prices represent over 300 per cent difference in the flat-rate charge for the same operation. It is the penalty that the owner must pay for lack of accessibility.

It is impossible on one six-cylinder engine to remove the No. 1 and No. 2 or the No. 5 and No. 6 piston and rod assemblies, without first removing either the cylinder-block or the crankshaft. If the owner has the misfortune to burn out a connecting-rod bearing of either of these cylinders he has a very heavy maintenance charge to meet.

Mr. Herrington cited one car as a very bad example of inaccessibility for starting motor repairs. In this car it is necessary to remove the clutch and the brake-pedal pads, disconnect the accelerator, remove the front toe-boards, remove the engine hood, disconnect the throttle and the gasoline line, and remove the carbureter and intake-manifold to remove the starter. It is certain that the owner of this particular car has just cause for complaint. The worst feature of this installation is that the mechanic has to disturb the carbureter and the inlet-manifold and may thus alter the satisfactory running of the engine.

The flat-rate charges for adjusting valves upon five well-known cars, the engines of which all have the same number of cylinders, is as follows:

Car	Price
A	$1.00
B	1.50
C	1.80
D	3.00
E	3.60

Again we find a wide variation all of which is caused by the amount of work necessary actually to get at the tappets to make the adjustment. To reline and adjust the foot and the hand-brakes on cars of the same approximate size and weight charges are made as follows:

Car	Price
A	$29.00
B	30.50
C	32.80
D	33.50
E	39.00

It is surprising that such a variation upon a part of the chassis which is as nearly standardized as rear-wheel construction exists. A slight investigation will develop that this is easily possible.

The proper location of grease-gun connections is a matter that is extremely important and is very often done in a slip-shod manner. Mr. Herrington mentioned one chassis at the New York Show that had nine grease-gun connections located under the body in such a manner that they could only be reached from below the chassis. In many designs the brake cross-shafts are located under the frame cross-members and under the seats of the body in such positions that they cannot be reached by lifting either the front or the rear foot-boards.

Two eight-cylinder cars of about the same displacement and price class show a wide difference in the cost of replacing the radiator rubber-hose connections. The material required upon car *A* is as follows: One piece of water hose 4 in. long and 2 in. in diameter and one piece 6 in. long and 2 in. in diameter. It also requires four hose-clamps and four joints must be made water-tight.

The material necessary for car *B* is

Number of Pieces	Length, In.	Diameter, In.
2	7	1¼
2	7	1⅛
1	6	⅝
2	18	1¼
2	4¾	1¼

This makes a total of nine pieces of three different sizes of hose. It also requires nine hose clamps of three different sizes and 18 joints that have to be made water-tight. The comparison of the necessary labor and material in each instance is too obvious to warrant further comment. Mr. Herrington cited other examples of inaccessibility some of which were so ridiculous that it is difficult to understand how designers could pass these errors on to the car-owner.

Two ways suggest themselves for making a quick estimate of the accessibility of any design. First, determine how many special tools have to be provided to effect inaccessible

adjustments. Second, compute the total number of parts used in assembling the car. The average chassis occupies so many cubic inches of air space and it seems logical that the more parts the designer crowds into this limited space the more difficult it will be to get at these parts.

By insisting upon the flat-rate system, the purchaser of automotive transportation has served notice upon the industry that he is interested in the cost of maintenance. The more accessibility that is brought into a design the better satisfied the user will be and the maintenance charges on his car will be lowered proportionately.

Several interesting points were brought out in the discussion. For example, W. S. James, of the Bureau of Standards, wondered whether a scheme of replaceable units might not come into general use. In other words, an owner wishing to have a transmission repaired would have the transmission replaced entirely by a unit in satisfactory condition. It might be arranged that he keep the "spare" transmission or he could call again for his own transmission when the repairs were made on it. This system is used by taxicab companies and the Motor Transport Corps. Some discussion of the possibility of a central service-station equipped to handle all repairs at a minimum cost rather than to divide the work up among a number of small stations with inadequate equipment followed. C. H. Warrington, chairman of the Washington Section, who is also a distributor of passenger cars, said that he was using the flat-rate system in his establishment. He did not believe that the full value of the system would accrue to the motorist until material costs as well as labor charges are included in all flat rates.

EFFECT OF BALLOON TIRES ON BRAKING

New Bureau of Standards Test Data Raise Interesting Engineering Questions

JOHN R. CAUTLEY

It remained for the Pennsylvania Section to introduce the subject of four-wheel braking with a man's-size brass band! Possibly it was felt that the playing of martial airs might enliven the discussion of this talk-worn subject, but such forethought was hardly necessary in this instance. Nevertheless the originality of the Philadelphia ringmaster, A. K. Brumbaugh, was commended generally and the assemblage enjoyed the surprise concert given by the Autocar band. John R. Cautley, vice-president of the Perrot Brake Corporation, opened the program with a paper on four-wheel braking, laying particular stress on the minimizing of pedal-pressure and pedal travel by the introduction of some form of servo-mechanism. W. S. James repeated his annual meeting paper on the Bureau of Standards brake investigations and presented data from more recent tests which throw some light on the actual effect of balloon tires on braking. E. V. Rickenbacker was present and participated in the discussion.

QUICK-STOP DEMONSTRATIONS DISCOURAGED

Freak demonstrations of quick stopping made to impress prospective customers are bad business, said Mr. Cautley. Much more important are the ability to stop reasonably quickly but safely on slippery pavement; the ability to control the car on curves; the ability to run greater distances without brake adjustment; the ability to brake on long declines without excessive heating; and many other advantages. Stress should not be laid on the one advantage of quick stopping simply because it is the easy thing to demonstrate. The average driver can and should be educated to regard the extreme use of four-wheel brakes as an emergency measure.

It is Mr. McCautley's opinion that power-operated brakes will have a difficult time surviving in this Country because they add complication and expense. It is possible that power-braking may be favored for high-speed buses. Satisfactory self-contained servo-brakes have been developed which build up manual pedal-pressure and make power-braking unnecessary. Finally, power braking is likely to be dangerous except in the hands of trained operators.

Advocates of hydraulically operated brakes claim a high efficiency for this system and a low one for mechanical operation. Mr. Cautley believes that a mechanical transmission of pedal pressure can be designed to have a high efficiency if the layout is correct. Simplicity, sturdiness and a proper balance in the torsional members for both front and rear brakes are necessary to attain this high efficiency. While four brakes on four wheels can be made almost as cheaply as four brakes on two wheels, really good brakes cannot be got unless car builders see the need of spending more money on brakes than they have been spending in the past. Brake-drums are being improved and will have to be improved still further, no matter what types of brake are used. Wide limits for eccentricity cannot be tolerated.

SOME INTERESTING OPINIONS ON SKIDDING

After discussing the Perrot servo-brake, which has been described in these pages,[1] Mr. Cautley offered the following conclusions of the engineers of his company, these being based on recent mathematical investigations checked by tests of small model cars:

(1) Front-wheel brakes practically never cause rear-rear-wheel skids and vice versa

(2) Lack of equalization of braking effect is not serious up to 20 per cent so long as two or more wheels are rolling

(3) Bad skids come from sliding too many wheels at one time

(4) Front brakes exert an actual force resisting rear-wheel skids in running straight ahead and on curves

(5) If a car is turning a curve and the brakes are applied, it is more liable to skid if all wheels are locked than if two or more are rolling. This is one case where unequalized brakes are superior

DO BALLOON TIRES INCREASE BRAKE EFFECTIVENESS?

Many extravagant claims have been made for the balloon tire as a braking adjunct. They range downward from the statement that a car fitted with balloon tires and rear brakes will stop as quickly as a car equipped with high-pressure tires and having brakes on all four wheels. In an effort to prove or disprove these claims, the Bureau of Standards conducted a series of comparative tests on a six-cylinder car weighing 2900 lb. and fitted with mechanically operated four-wheel brakes. Deceleration records were taken with the Bureau of Standards recording decelerometer[2] and these were converted into equivalent coefficients of friction between the tires and the road for purposes of comparison.

In the first series of runs, the car was equipped alternately with three sets of 32 x 4-in. high-pressure cord tires of different make. Stops were made with each set of tires inflated to pressures of 25 and 50 lb. per sq. in. on both wet and dry concrete pavement. Mr. James submitted data from this group of tests presented in Table 1.

It is interesting to note the wide variation in the performance of tire *A* as compared with the uniform performance of tire *C*. The effect of the lower air-pressure was not the same for the three tires; on the dry pavement, the co-

[1] See THE JOURNAL, February, 1924, p. 101.

[2] See THE JOURNAL, December, 1923, p. 499.

TABLE 1—COEFFICIENTS OF FRICTION WITH HIGH-PRESSURE TIRES

Tire	*A*	*B*	*C*
Tire Pressure 50 Lb. per Sq. In.			
Dry Concrete	0.72	0.77	0.76
Wet Concrete	0.65	0.71	0.75
Tire Pressure 25 Lb. per Sq. In.			
Dry Concrete	0.74	0.73	0.77
Wet Concrete	0.72	0.76	0.76

efficient of *A* increased, *B* decreased and *C* was practically unchanged; on the wet pavement all coefficients increased over the high-pressure figures. Mr. James did not attribute these peculiar variations to tread configuration but believed the character and the cure of the tread rubber influenced the results.

After these tests with high-pressure tires, the same car was tested with two different sizes and makes of low-pressure tire inflated to different pressures. The readings in this case were as given in Table 2.

The figures for a dry road and 30-lb. air pressure show little change from those in Table 1. All of the other results, however, show an increase over the corresponding high-pressure figures and substantiate the claim that balloon tires do improve brake performance. Peculiar variations are again apparent in Table 2. The larger balloon tire was not affected by the condition of the pavement but the coefficients of the 5.25-in. tire changed materially. It is also of interest to note that the smaller tire was much more effective in shortening the car stop. Mr. James offered no explanation of this but left it for the members to ponder upon.

Internal Brakes Favored By Rickenbacker

E. V. Rickenbacker outlined the experiences of his company in the development of a satisfactory four-wheel braking system. He said that cable-operated brakes had to be abandoned due to difficulties caused by the stretching of the cables.

If satisfactory non-stretch cable could be procured, it would reduce the manufacturing cost of four-wheel brakes and facilitate production. Contracting external brakes were tried and abandoned by the Rickenbacker Company because they overheated on long hills and their operation was affected by mud and wet weather. Mr. Rickenbacker expressed a preference for rigid expanding internal brakes with equalizers in each wheel, the system being arranged so that the rear brakes are applied just before the front, thus reducing the skidding tendency when turning corners. He championed the graduation of pedal-pressure so that greater foot-pressure must be exerted when increased brake-action is needed. If the pedal-pressure is too light, the driver is enabled to lock all wheels when applying the brakes suddenly as in an emergency, and this is a bad condition in Mr. Rickenbacker's opinion. He was not optimistic about the future of the hydraulic system of brake application, though he admitted that its simplicity made a strong appeal to the average motorist of today. In closing, he predicted that four-wheel braking would be the universal practice within a few years.

Braking of Heavy Trucks and Busses

Pedal travel of 5 in. is not adequate to cover the variations in brake adjustment and the expansion of the brake-drums, said B. B. Bachman. Power application of brakes may be essential in the case of very heavy vehicles for this reason. In driving a passenger car fitted with four-wheel brakes he had noticed that it was no longer possible to apply the brakes satisfactorily by merely rocking one's foot about the heel; the increased pedal-travel necessitates raising the whole foot when depressing the pedal.

R. R. Wittingham, vice-president of the Atlas Axle Co., said that some form of servo-mechanism is absolutely essential for the satisfactory braking of heavy trucks. Weights of trucks and buses are much greater than those of passenger cars, yet the same limited impelling force, the driver's leg muscles, are relied on to stop the heavier vehicle. The only way to magnify this is by increasing the pedal-travel or fitting some form of servo-mechanism. The split-shoe or Perrot form of internal servo-brake increases the effectiveness of the driver's foot-pressure four to five times. Power brakes may be satisfactory on public service equipment where they will receive proper attention, but it is improbable that they will ever be used on passenger cars generally. Mr. Whittingham stated that it is possible to lock the wheels on a 25,000-lb. vehicle by applying 75-lb. pressure to the brake-pedal if the split-shoe servo type of internal brake is used.

A. E. Hutt, general manager of the Philadelphia Rural Transit Co., said that he would not adopt power braking for buses if it could be avoided. It would tend to further complicate the bus chassis. He felt that four-wheel braking will be adopted for buses largely because the available area inside the base diameter of the rear wheels must be used up entirely for service brakes. This almost necessitates mounting the hand or emergency brakes on the front wheels. Alvin Yocom, chief engineer of the U. S. Axle Co., also contributed a brief discussion.

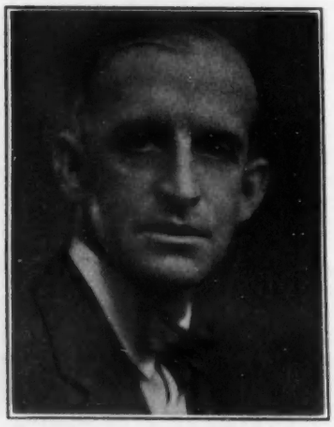
TABLE 2—COEFFICIENTS OF FRICTION WITH BALLOON TIRES

Balloon Tire Section, in.	5.25		6.20	
Condition of Road Surface	Dry	Wet	Dry	Wet
Air pressure, lb. per sq. in.				
10	....	....	0.80	0.80
15	0.81	0.84	....	....
20	0.80	0.83	0.78	0.77
30	0.74	0.84	0.76	0.76

[1] Experimental engineer of chassis lubrication, Bowen Products Corporation, Auburn, N. Y.

CHASSIS LUBRICATION

Detroit Discusses Centralized and Magazine Oiling—Rubber Shackles Described



Fred H. Gleason

Grease-cups, oil-cups, reservoir with wick-feed, reservoir with pump-feed, and grease and oil-guns with suitable connections were mentioned as the common systems of chassis lubrication by F. H. Gleason,[1] who presented a paper on a centralized system at the April 3 meeting of the Detroit Section. The paper was printed in full in the April issue of The Journal on p. 422.

In the system described a central oil-reservoir and pump are connected to a main supply-line that leads to one or more control headers from which delivery tubes extend directly to the points or the bearings to be lubricated.

The following claims and conclusions were mentioned with reference to the system:

(1) A simple, dependable chassis-lubrication system that will lubricate all chassis bearings efficiently can be incorporated in the chassis with few complications and very little added expense

(2) Longer life, the elimination of annoying squeaks and rattles and improved riding and handling qualities will result from the adoption of this system

(3) The reservoir and the pump constitute a sturdy unit that will function during the life of the chassis with no attention other than that required for filling the reservoir and occasionally cleansing the screen in the drain-plug

(4) The system of oil-delivery control is such that

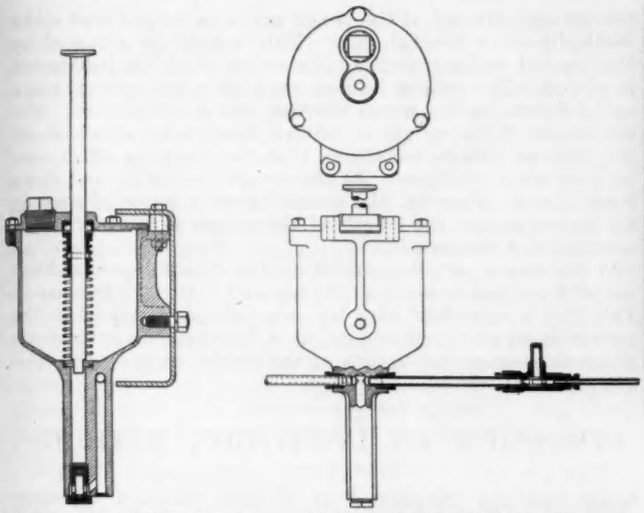


FIG. 1—THE RESERVOIR AND THE METHOD OF CONTROL IN A CENTRALIZED LUBRICATION SYSTEM FOR AN AUTOMOBILE CHASSIS

The 1-Qt. Cast-Iron Reservoir Has a Cylinder at the Bottom in Which a Plunger with a Foot Button at the Upper End Operates. Normally the Plunger Is Kept in the Position Shown by a Spring and a Stop Collar and When in This Position the Milled Portion at the Lower End Acts as a Guide and Also Provides a Passage for the Oil from the Reservoir to the Cylinder. The Lower End of the Cylinder Is Closed by a Combined Screen and Drain-Plug That Permits Complete Drainage of the Reservoir and the Pump Cylinder and Cleaning of the Screen. The Oil Passes through the Fine-Mesh Screen before It Can Enter the Lines of Tubing Leading to the Bearings

⅓ cu. in. of oil will lubricate the bearings of the average chassis efficiently, so that every bearing surface will show a film of oil. Lubricant is not forced out around the outlets to soil the chassis and collect dirt. Any predetermined volume of oil, from 1 drop to any desired volume, is delivered positively at each outlet every time the pump plunger is depressed

(5) The system of oil delivery provides for a shot of oil at each bearing immediately after the pump plunger is operated and for a continuous, slowly decreasing feed for several hours

(6) The oil pressures developed at the outlets with one stroke of the pump plunger vary from 1 to 10 lb. per sq. in., depending on the volume of oil delivered and the fit of the bearing supplied

(7) Failure in one or in any number of delivery lines will not affect the operation of the remaining delivery lines

(8) The system will lubricate efficiently a chassis operated at sustained low temperatures

(9) The constructions employed to lubricate various chassis units provide means to lubricate these units with adequately protected tubes and connections that move as a rigid part with the unit, thus eliminating swivel connections and projecting parts that are subject to damage. Once properly installed, they will function during the life of the chassis

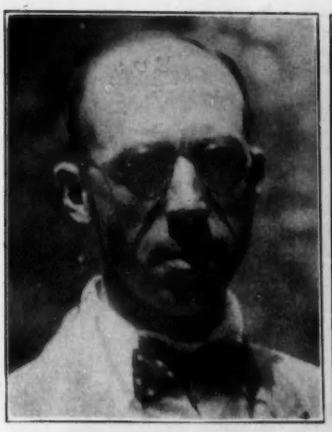
(10) In general, all service-work on the chassis can be accomplished without disturbing the connections or the tubes of the lubrication system

MAGAZINE OILING SYSTEM DESCRIBED

Chassis lubrication by the magazine oiling system was advocated by C. T. Myers,[2] whose name has long been associated with this very important subject. In his remarks Mr. Myers described the details of the system developed by him and cited examples of faultless operation on many vehicles over extended periods of time.

Briefly, the system consists of small oil magazines attached to each bearing or group of bearings. Light oil is slowly and automatically fed to each bearing whenever needed, by a large felt wick. The latter also filters out dirt and excludes moisture from the bearings. Details of the system have appeared from time to time in THE JOURNAL.

[2] Chassis Lubricating Co., Rahway, N. J.



C. T. MYERS

A. F. MASURY

It was stated that cast magazines have been used to a great extent, but that their application to passenger cars often requires a change from forgings and stampings to castings. To obviate this a pressed-steel device has been developed. Attention was called to an ingenious quickly detachable cap with which the device is equipped. Slides were shown.

None of the magazines need be filled more than four times each year and in some cases a 6 months' supply of lubricant

FIG. 2—RUBBER SHACKLE OR SHOCK INSULATOR MOUNTED IN BRACKET

Part of the Bracket Has Been Cut Away To Show How the End of the Spring Is Held in the Rubber Block

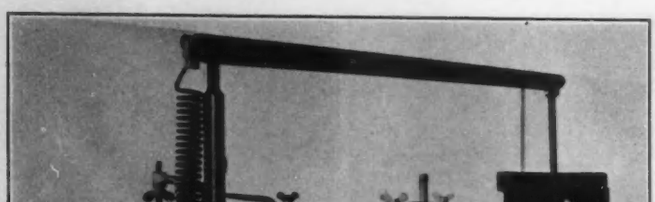


FIG. 3—SEISMOGRAPH USED TO DETERMINE RIDING QUALITIES
The Paper Record Chart Is Rolled from the Storage Spool at the Left to the Record Spool at the Right as the Latter Is Rotated by a Flexible Drive from a Front Wheel of the Vehicle. The Seismograph Weight Moves Vertically Along Guides as the Instrument Encounters Vertical Jolts; a Pencil Attached to the Weight Records the Movement upon the Chart by a Pencil Actuated from a Phonograph Motor Properly Governed

is carried. Many operators employ "used" crankcase oil as a lubricant.

RUBBER SHACKLES ELIMINATE OILING

Improvement of riding qualities, reduction of spring breakage and elimination of spring-shackle lubrication were among the advantages claimed for rubber spring-shackles or "shock insulators" by A. F. Masury[3]. A detailed account of this recent development will appear in an early issue of THE JOURNAL.

Briefly the insulator consists of a block of live rubber fashioned so as to accommodate the end of an automobile spring; the block in turn is held under compression in a housing or bracket suspended from the frame. Both ends of each spring are mounted upon a rubber shackle. Fig. 2 presents a view of the installation for the rear end of a spring. Parts have been cut away to show the arrangement clearly.

Motion pictures of the device in action showed very clearly the movement of the rubber as the spring deflected. However, no relative motion of the bearing surfaces between the rubber and the metal took place. Improved riding characteristics of cars equipped with the rubber shackles were determined by a special seismograph shown by Fig. 3. The following details of the seismograph are of interest:

Mounted in a rigid steel frame is a metal drum upon which is wound the record paper from a spool at the opposite end of the frame. The axis of the drum is vertical and is driven through worm gearing; the worm shaft being driven from the front wheel by a flexible shaft. On the upper edge of the drum are 10 cams equally spaced, which trip a pencil holder and record distances of 1/10 mile or 1/320 mile, depending on the ratio used.

A phonograph motor is mounted near the recording drum and trips a pencil that marks periods of time near the bottom of the record. The motor is governed to record seconds.

The seismograph pencil is held on a light arm pivoted on single-point bearings and provided with an aluminum leaf spring to hold the pencil against the record paper. The pencil arm is horizontal and is tangent to the drum, the recording pencil touching the paper at the point of tangency. On the opposite end of the pencil arm is a weight that slides vertically on a central post. This weight is actuated by the vertical movement of the chassis on which the instrument is placed. The weight is supported by a coil spring below and a lighter spring above prevents excessive rebound. The movement of the weight is further damped by an air dashpot with adjustable valves, so that the damping effect may be accurately regulated. As the weight moves up and down from chassis vibration, the pencil leaves a series of arcs on the record paper, the length of these arcs varying with the movement of the weight.

A stationary pencil mounted on the frame leaves a horizontal line midway between the top and bottom of the paper. This line is coincident with the seismograph pencil when the vehicle is at rest, and is used as a base line or guide from which to measure the length of the marks made by the seismograph.

[3] Vice-president and chief engineer, International Motor Co., New York City.

SYMPOSIUM ON INSPECTION METHODS

Keen Interest Displayed at Detroit Section Meeting Dealing with Subject

Inspection methods practised in the Packard, Lincoln, Cleveland and Studebaker shops were the subject of an exceptionally valuable meeting of the Detroit Section on April 17. This was the first meeting of the Society devoted entirely to the subject of inspection. It was very evident from the reception given the papers and from the intense interest shown by the audience of nearly 100 men, that this field is a fertile one for the Society to cultivate.

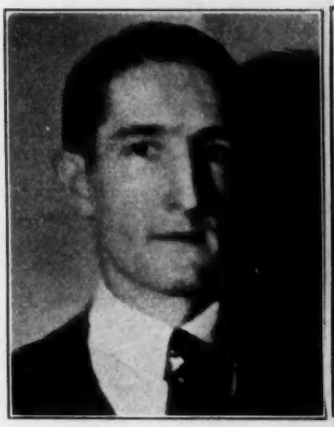
HOW PACKARD INSPECTS THREADS

C. S. Stark, chief inspector of the Packard Motor Car Co., discussed a few important points on the inspection of processed material in his paper. Many different methods of gaging and inspecting threads were tried in the Packard shop before arriving at their present methods. External and internal "Go" and "No-Go" gages, lead indicators, projectors and many other types of specially constructed gages for checking both pitch and lead were used, but each of these was found to be an expensive proposition. This experience led to a search for a more economical and at the same time a more accurate method for the inspection of threads, so that the exact condition of the product could be intelligently determined by as few movements as possible. For many years, Packard used its own standards for screw threads, but it was finally decided to adopt the S. A. E. Screw-Thread Standard, specifying tolerances that would result in a wrench fit.

It was finally decided that the thread gaging for the S. A. E. Standard should be performed by internal and external gages of the "Go" and "No-Go" types, having only three threads in actual contact with the work. Thus the accuracy of the pitch could be checked immediately by one movement, not by a point contact as would be the case with snap gages, but by a cylindrical check, taking it for granted that a little variation in the lead of three threads is of no material disadvantage. It was also found that this type of gage functions easier and was not so trying on the inspector. The wear is not so great as that of the 10 or 14-thread gage that wears bell-mouthed very quickly. With this three-thread type of gage, there is very little bind and if any is present, it immediately indicates pitch or root diameter trouble. These gages are marked "Go" and "No-Go," as well as with the pitch diameter and the number of threads per inch.

Lead indicators are used to check the lead. These indicators are not of any particular type. For ordinary machine screws, a tolerance of 0.003 in. per in. is allowed. On all work on which more than 1 in. of thread is cut, a tolerance of 0.0015 in. per in. is allowed. This system of inspection for external threads has materially reduced the number of inspectors engaged in this type of inspection and it has been found that a better product reaches the assembly departments as a result.

On internal threads, particularly on the smaller sizes, under ⅜ in., accurate threads are secured by using special ground taps. These taps are inspected rigidly to close tolerances. The pitch diameter is held to a plus 0.0000 minus 0.0005-in. limit and the lead is held to 0.0005 in. per in. The inspection covers the actual tapping of a number of holes. In addition to these tests, the pitch diameter of all taps is calibrated by the three-wire standard. As a final or master check, all taps are placed in a Hartness screw-thread comparator. Mr. Stark said that he believed the tap and die manufacturers are cooperating and progressing with the desire to secure more accurate threads. He could not say as much for the machine-tool designers and builders, for he doubted whether they have really given the matter of threading serious thought. It is wrong to attempt to use accurate taps in machine tools where no proper provision is made to maintain the lead. Considerable friction or resistance is allowed to take place when the tap is required to drag along turrets, tools and any other part of the mechanism.



A. H. Frauenthal

C. S. Stark

Method of General Inspection for Small Parts

For the inspection of small parts such as screws and nuts, a type of inspection known as general inspection has replaced the percentage system in the Packard shop. Stock to be inspected may be in lots of from 100 to 50,000, but instead of the usual practice of determining a positive percentage of the parts to be checked, and to overcome the tendency of merely scraping a panful of work from the top of the original lot, the inspector is trained to distribute the entire contents of the container on the bench, thus spreading the work out before him so that he can quickly visualize the general condition of the material. Then, by picking up a piece here and there at random from an area of say 1 sq. in. or so and inspecting carefully to blueprint and gages for this piece, the inspector will be able to determine very quickly the exact percentage of defective work contained in this individual lot. It then becomes merely a problem to determine what percentage of defective work will be permitted to reach the stockrooms. If the inspector finds the percentage to be greater than that allowable, it is sent to another inspector to be given detail inspection. This detail inspection can be performed by a cheaper grade of inspector, thus conserving the time of the skilled inspector who is responsible for the general inspection. Mr. Stark said that the quality of parts reaching the stockrooms has been improved by using this general inspection method in place of the percentage system and it has also effected economies in inspection costs.

Packard inspectors are denied the responsibility of exercising any judgment whatsoever in passing material that is not entirely up to the blueprint. The inspector has just one function to perform; to separate the work before him strictly in accordance with the gages supplied him, or to examine for defects visually in accordance with the visual standard supplied him. Any variations from this are considered sufficient for his individual rejection. All rejected material is placed on a special bench in each department and considered dead material for the time being. The responsibility of disposing of this dead material is vested entirely in a committee of three men, consisting of the mechanical superintendent of that division, the general superintendent of manufacturing and the chief inspector. Once each day, this committee visits a number of departments according to a definite schedule. They examine all rejected material, note the defects recorded on the tags attached and immediately decide as to the final disposition. The chief inspector makes the final disposition, thus limiting this important decision to a single individual.

Influence of Handling on Inspection Cost

A. H. Frauenthal, chief inspector of the Chandler Motor Car Co., cited some interesting examples of time study made to reduce inspection cost. He told of one instance where an arrangement had been made to allow an inspector using a scleroscope to compress the bulb with a foot pedal instead of with his hand. When using the bulb method the left hand of the operator was used to handle the clamp that held the work and the right hand was used to operate the bulb and also to rotate the piece being inspected. This unnecessary movement of the right hand to the bulb and back to the work and vice versa was eliminated by using the foot pedal. An experienced operator required 7.8 sec. per piece by the hand-bulb method and this was reduced to 6 sec. by the foot-pedal method, thus showing a saving of 30 per cent. Mr. Frauenthal described some interesting multiple gages that check a number of different points simultaneously on a given piece. These will be illustrated in a later issue of The Journal. One of these examples was a fixture used for checking water-pumps which checks 10 different items at one time. Another fixture he described is used for checking the spiral gear on the camshaft and its mating gear on the oil-pump, and making the customary camshaft inspection. This is all done on the single fixture. The doubling up of inspection in this manner cuts down initial gage cost and eliminates a separate operation. The actual movements thus eliminated by the fixture just mentioned are the picking up and laying down of the camshaft or the oil-pump gear. It is hoped to publish Mr. Frauenthal's paper in an early issue of The Journal.

The Lincoln Policy of High Quality Inspection

C. J. Jones, chief inspector of the Lincoln Motor Co., presented an interesting outline of the inspection methods of his company which indicated the thoroughness with which the Lincoln product is examined. He said that it was not possible for the inspection department to maintain a high quality of production without the best of cooperation between the engineering and the production departments. All factory department heads in the Lincoln organization are asked to live up to the slogan, "Is it good enough for you?" In selecting men for inspection work, the entire plant is canvassed to pick out the very best material. To get the right caliber of men it is sometimes necessary to take them from the production organization where they have been in charge of work that makes them familiar with the particular parts or line the inspection of which will be under their direction. The Lincoln inspection department works hand in hand with the engineering department and insists upon every part being made according to specifications. This applies to specifications on material as well as on manufactured parts. All parts received in the factory from outside sources are given a complete and detailed inspection. A detailed inspection of all parts from one operation to another is insisted upon all through the Lincoln plant. This reduces to a minimum the chances of defective parts getting through the final inspection and also stops further work on parts that are found to be defective. All electrical units are given complete and detailed inspection with precision instruments, and any part that does not measure up to the standard is rejected and returned to the vendor. It has been found that this reduces electrical trouble on final assembly line to a minimum.

Studebaker Screw Checking Methods

K. L. Herrmann gave some interesting sidelights on how screw-thread precision is maintained in the Studebaker factory. A corps of inspectors is kept busy at all times inspecting the screws turned out by each of the several screw machines. These screws are checked on a comparator and if any fault is found with them, the machine is ordered shut-down until the cause of the error can be eliminated. Mr. Herrmann made a strong plea for the use of ground taps. Nothing but ground taps are used in the Studebaker shop. Some trouble is being experienced in securing taps that are ground within suitable tolerances. It is Mr. Herrmann's belief that if all manufacturers will demand this degree of accuracy from tap makers, the latter will make a sincere effort to hold to the tolerances.

Chasers have been one of the chief sources of trouble in the Studebaker shop. These are now all checked by comparators for lead, trackage, squareness of back taper, clearance and the like. Accurate chasers are extremely hard to get.

Mr. Herrmann assured those present that the ground tap would be found the cheaper in the end. It may cost three times as much to begin with, but if accurate records are kept of its performance, it will be found that the cost of holes tapped per dollar is one-half that of the ordinary tap.

In the general discussion many interesting points were brought out. Mr. Stark said that the Packard Company takes its factory foremen from the inspection department. This is directly opposite from the practice at the Lincoln plant. In reply, Mr. Jones said that production men know many tricks that are practised to pass inspection and this is one reason for picking inspectors from the production division. The question was asked whether vendors should be supplied with inspection gages or not. Mr. Frauenthal discouraged this practice, saying that it is not possible to control the manner in which the gage is used by the vendor and in many cases the gages are used as an alibi. He favors the practice of making the vendor adhere strictly to the blueprint. Mr. Herrmann contributed the interesting statement that one complete Studebaker car is scrapped out of every 300 built. Of course he meant that sufficient material for one car is scrapped out of every lot of 300 parts manufactured. All "salvage" limits have been eliminated by the Studebaker organization; the drawings are adhered to strictly. He cited one instance where 260 crankshafts were scrapped simply because of a minute error in one of the crankpin fillets. All departments are debited with the scrap for which they are responsible and are expected to stay within a specified limit. The discussion brought out the fact that no really accurate checking method exists for inspecting spiral bevel gears economically so that they will run quietly in the finished axle.

Before the close of the meeting the men present were asked whether they favored the holding of a series of inspection meetings in the Section year 1924-25. The resulting vote in favor of such meetings was almost unanimous and the Detroit Section is certain to arrange a series of papers and discussions limited specifically to inspection problems.

RAIL-CAR FUTURE LOOKS BRIGHT

Railroad Engineers View Units Optimistically and Will Cooperate In Development

Further steps in the development of successful and practical motor rail-cars were recorded at the meeting of the Midwest Section in Chicago on April 11. Most significant were the comments and constructive criticisms presented by railroad engineers who participated in the meeting. Papers were read by two engineers representing important Western railroads and they contain much food for thought. The opening paper of the group was read by M. L. McGrew of the International Motor Co., whose paper is given in abstract form in the following paragraphs.

The demand in the United States has been for mass transportation over long distances. Almost the entire energy and genius of development of our railroads has gone into the bigger things, such as the 20th Century Limited, the 7000-ton freight train, the 100-ton capacity freight car and the 136-lb. rail. Concentration on these bigger phases of railroad transportation has resulted in the equipment becoming less and less suited to the smaller phases of railroad transportation. Antiquated worn-out equipment is not economical for the handling of small-unit transportation. The operating expense of such equipment is much too high. Gasoline-propelled rail-cars meet the needs of this small-unit traffic satisfactorily. Development has been slow because many mistakes have been made in the early designs, but the experimental stage has now been passed. Successful rail-car units are now on the market and range in size from a car that seats 60 passengers or carries 30 tons of freight down to a car that can carry 25 passengers or 10 tons of freight. These cars are capable of operating at various speeds up to 50 m.p.h. They can be operated at an expense of 20 to 50 cents per car-mile, which is a figure very much below the cost of the equivalent steam transportation. These modern units require 1 hp. for each 500 lb. of weight. Less power than this does not give satisfactory performance and more power means unnecessarily high operating expense.

Types of Rail-Car Now in Use

Some storage-battery cars are in successful operation. Their field is particularly where the distances to be run are short and where charging facilities and cheap electric power are available at both ends of a run. Gas-electric cars have been used to some extent in the past and are again being built. The advantages of gas-electric installations are offset because of their greater weight and the inefficiency of transforming the motion of the engine into electric current and transforming this current back into mechanical motion at the axles. The Diesel engine is being used to some extent in Europe in combination with an electric drive. In this case the inefficiency of the drive counterbalances the greater efficiency of the Diesel engine.

Cars equipped with large single engines and mechanical transmission are operating successfully in this Country. In common with other rail-cars mentioned, they have the disadvantage of requiring engines of higher power than those for which any market exists outside of the rail-car field. This means that quantity production of the engine is impossible, and the solution of the problem seems to lie in the use of two or more powerplants of smaller size on each car, properly synchronized so that they can be used simultaneously to propel the car. This makes it possible to use engines, transmissions and other parts of a size commonly used in motor-truck operation and thus lowers the cost of these parts when used on rail-cars. The use of truck engines also improves interchangeability and makes it possible to purchase repair parts for the unit at almost any population center where motor trucks are used.

Rail-Cars Suited to Frequent-Stop Service

The obvious location for the gasoline rail-car is, of course, on the non-paying branch where the abandonment of all service is being considered. An equally good location for rail-cars is the in-between and local service on main lines. While all development of rail-cars has been in the direction of passenger traffic, no difficulty in the way of handling a limited amount of freight has been encountered. A small gasoline locomotive of about 30 tons can be built to handle the four and five cars necessary in these situations. Moreover, freight-car bodies can be put on the existing type of rail-cars to handle less-than-carload freight. The way is thus open for the abandonment of steam as a motive power in many places with the consequent large saving of operating cost. Unquestionably the rail-car has come to stay.

New Rail-Car Described

Mr. McGrew gave a complete description of the rail-car shown in the accompanying illustration. This car is mounted on two trucks, one of which has an engine and a transmission driving to one of the axles. The power truck is

complete in every detail, having a gasoline supply system, a cooling system and the exhaust system as well as the air compressor and the electric generator incorporated in the assembly. The car body can be made, within certain limitations, to be of any design to meet the needs of the purchaser. The car floor cannot be much less than 56 in. above the rail. The bodies are 54 ft. long and can be made with a 26½-ft. baggage space and seats for 30 passengers, or the baggage space can be omitted and the car will then seat 60 passengers.

The control equipment is somewhat similar to that used on subway and elevated trains, consisting of a controller for the engine, another for the shifting of gears and the customary airbrake valve. An indicator system is furnished so that the driver can visualize the operating condition of the several power units, when more than one is used.

The trucks consist of a pressed-steel riveted frame carried on American Railway Association 4¼-in. class A axles with 3¾ by 7-in. journals. The wheels are rolled steel, 30 in. in diameter. The journal boxes are carried in cast-steel pedestals riveted to the main frame. Coil springs are provided over the journal boxes.

Four-Cylinder 60-hp. Engine Used

The power truck is furnished with a four-cylinder engine, 5-in. bore and 6-in. stroke, capable of developing a maximum of 60 hp. This engine drives the axle through a dry disc clutch, universal-joint, transmission and then a second universal-joint. The axle gears are the dual-reduction type. Control of the engine is secured electrically, through an electric controller at each operating position. The control of shifting of gears is accomplished electro-pneumatically. The actual shifting of the gears is accomplished by air cylinders whose pistons are connected to the shaft carrying the shifter forks and the clutch lever. All of these controls are automatic in operation, so that it is possible to operate more than one unit in parallel and it is also possible to operate two or more cars in parallel.

Ahead of the main transmission gearing, a spline shaft is provided on which two sliding gears are mounted. Shifting of these gears provides for reversing the drive and at the same time makes it possible to use all four speeds in either direction.

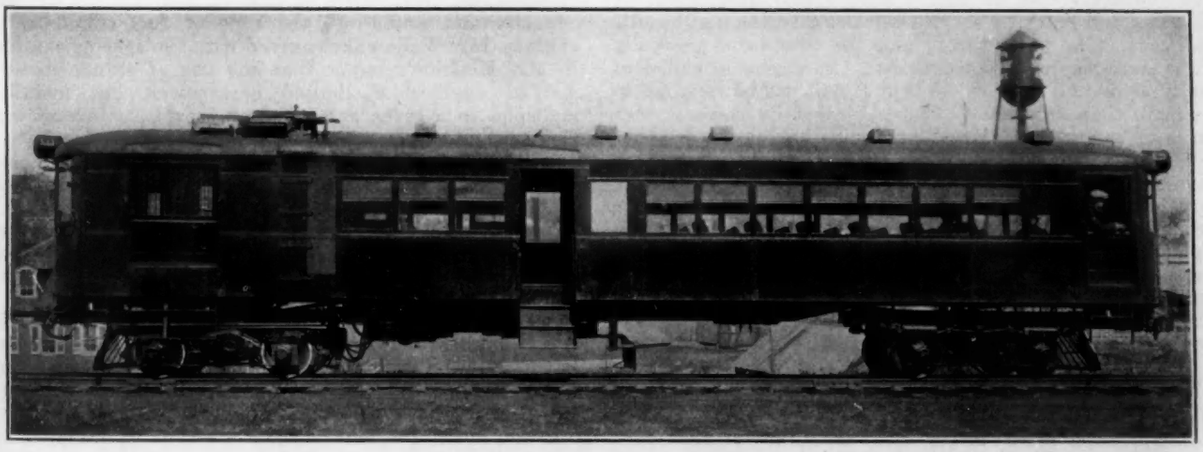
Railroad Engineer Gives Experience

Many constructive engineering criticisms and much practical experience were given in the paper read by E. J. Brennan, superintendent of motive power of the Chicago Great Western Railroad Co. The first installation of rail-car equipment was made by this line in 1910. Three cars

Four Speakers at the Mid-West Section Meeting of April 11
From Left to Right They Are E. J. Brennan, Superintendent of Motive Power of the Chicago Great Western Railroad Co.; M. L. McGrew, International Motor Co.; E. Wanamaker, Electrical Engineer of the Chicago, Rock Island & Pacific Railway Co., and L. G. Plant, Formerly Technical Editor of the *Railway Review*

were put into service at that time and these were powered with 200-hp. six-cylinder engines of 10-in. bore and 12-in. stroke. The engines were located on the front driving trucks. Mr. Brennan said that many troubles were experienced with these original cars and this led him to believe that the four-cycle reversible type of engine is the direct cause of many rail-car difficulties. The engine on one of these cars was lubricated through an oil pipe feeding from a 14-feed mechanically operated lubricator. It was found that this mechanism was entirely too intricate for railroad service and these engines did not give as good service as those in the other two cars that were lubricated by splash. These three original cars are still in operation, but a great many changes have been made in them and their equipment. They operate for about 35.00 cents per mile singly and for 40.14 cents per mile when pulling a trailer. The weight of these original Chicago Great Western rail-cars is approximately 35 tons.

A second type of gasoline rail-car was installed by the Chicago Great Western Railroad Co. in 1922. The coach of this train is 28 ft. long, has a 12-ft. baggage space and carries 30 passengers. The total weight is 28,000 lb. The trailer is 32 ft. long, weighs 17,000 lb. and has a seating capacity of 36 passengers. It was originally fitted with a four-cylinder 65-hp. engine, but it needed only a trial trip to show that the engine was not of sufficient capacity and a six-cylinder 105-hp. engine was installed. Further experience showed that insufficient radiator capacity had been provided and that the drive was not substantial enough. Frequent changes have been made in this unit and at present Mr.



A Recently Developed Rail-Car
This Car When Built as Illustrated Will Seat 30 Passengers. If the Baggage Space, Which Occupies Approximately One-Half of the Car, Is Omitted, the Seating Capacity Is Increased to 60. The Powerplant Is a Four-Cylinder 60-Hp. Engine That Drives the Power Axle through a Dry Disc Clutch, a Universal-Joint, a Transmission and a Second Universal-Joint. A Controller Similar to Those Used on Subway and Elevated Trains Regulates the Speed of the Engine and the Gears Are Shifted Electro-Pneumatically through Air Cylinders Whose Pistons Are Connected to the Shaft Carrying the Shifter Forks and the Clutch Lever

Brennan is having heavier shafts and joints or more than double the strength of the original equipment installed. The original trucks under this gasoline train were equipped with ball bearings, but it was found that the balls would chip, lock the bearings and failure would then result. The trucks were also rigid and this caused undue vibration and, regardless of how the various units were fastened to the truck, they would invariably shake loose. It was necessary to apply a larger oil-pump on these engines so that a pressure of 40 lb. per sq. in. was carried on the crankshaft bearings at full speed. With the original oiling system one connecting-rod failure was experienced each week, but since the system has been changed and the pressure increased, the engines can be run for 4 months before it is necessary to remove even a very thin shim. The starting and lighting systems were originally connected to the same storage-battery, but it was found that the battery would become exhausted during the layover period and it was necessary to install an independent generator and battery for the lights. Despite all of these changes, Mr. Brennan said that he was not discouraged in the least, but kept improving and strengthening these rail-car units as weaknesses developed. This two-car train operates over a round trip totalling 184 miles daily at a cost of $0.28 per mile.

One Car Runs 60,000 Miles without Major Overhaul

The next type of gasoline-driven rail equipment installed by the Chicago Great Western Railroad Co. was a car weighing 30,000 lb. and having a seating capacity of 38 passengers. It is equipped with a four-cylinder engine, 4¾ in. bore and 6-in. stroke which develops approximately 65 hp. This car is being used successfully on a light run making a round trip of 185.2 miles every day. To date it has operated a total of more than 60,000 miles without receiving a thorough overhauling. The drive in this particular unit is to all four wheels of the front truck and fabric universal-joints are used. Mr. Brennan said that no trouble had been experienced with this particular type of transmission.

In 1923, the company installed a rail-car of greater capacity. The coach of this train is equipped with a 225-hp. gasoline engine of the marine type. The car has a seating capacity for 30 passengers and a 16-ft. baggage space; the trailer seats 44 passengers. The train is operated daily over a distance of 216 miles and has proved to be a very successful venture as compared with the road's previous experience. This train operates at an average cost of 24.89 cents per mile, including all operating and maintenance costs.

Things That Need Correction in New Designs

Mr. Brennan said that his long experience with gasoline-driven equipment has led him to believe that units built for commercial and trucking service will not give the best results in rail-cars. The parts throughout the equipment generally must be more rugged in construction. An engine of sufficient capacity should be installed so that it will not be required to exert more than from 60 to 65 per cent of its power except in cases of emergency. Motor-car lamps having the bayonet type of base are unsatisfactory for rail-car use; the standard Edison-base lamp must be used. The present system of generation and storage in the electrical system could be materially improved upon by using an axle-driven lighting equipment and it is the recommendation of the Chicago Great Western engineers that a device of this character consistent with the size and the type of gasoline-propelled car utilized on steam railroads be developed. Such an axle-driven lighting device could be attached to the rail-car and the trailers could be illuminated by train-line connectors. Mr. Brennan has found the center type of lighting to be more practical and economical than side illumination.

Believes U. S. Standards Must Be Used

In the design of satisfactory rail-car equipment, the comfort of the passengers is a very important requisite. The cooling capacity of the engine must necessarily be ample. All bolts and nuts whenever possible throughout the entire equipment should be U. S. Standard instead of S. A. E. Standard, in Mr. Brennan's opinion. All railroad shops are stocked with U. S. Standard parts and the railroad engineers do not wish to have another standard introduced into rail-car practice. By adhering to the U. S. Standard, the stock of utility parts decreases about 12 per cent. There is also the possibility of error in mixing nuts and bolts when the repairs are made by the class of help generally found in railroad yards.

L. G. Plant, former technical editor of *Railway Review*, said the railways and their regulating bodies should be willing to accept considerable modification in the weight and the structural strength of rail-cars in comparison with the all-steel passengers-cars of today. He said that a very satisfactory gasoline-engine-propelled car seating over 40 passengers has been built to weigh less than a single six-wheel truck under a standard Pullman sleeper. It is essential that gasoline rail-cars be equipped with more than one engine, according to Mr. Plant. With all their other faults, it is probable that gasoline rail-cars of older design would have enjoyed reasonable success had it not been for the engine failures that so frequently tied up this equipment on the road or in the terminal. The development of a gasoline rail-car generally adapted to railroad requirements is yet a pioneer undertaking. Mr. Plant said that he had been impressed with the courage and the patience it has required to accomplish the development thus far. With the cooperation of the railroads, it is certain that so sincere and well-directed an effort will lead to lower operating costs and better service through the general use of gasoline-driven rail-cars.

Rock Island Engineer Thinks Two Cars Needed

E. Wanamaker, electrical engineer of the Chicago, Rock Island & Pacific Railway Co., read an extremely interesting paper. He felt most optimistic toward the introduction of the internal-combustion-engine drive to railroad service, but believed that no particular benefit would be derived from its introduction by making minor improvements to such equipment as has been built for other service. To adopt the use of internal-combustion-engine drive on steam railroads successfully it is necessary that engineers work along the lines of radical changes or radically new developments. Mr. Wanamaker felt that we may soon look for a tremendous sweep of internal-combustion-engine drives over our railroads. After touching upon the matter of fuel supply in the future, he said that the inflexibility of the steam locomotive is alone sufficient to cause its retirement as regards its meeting the requirements of modern light service.

He believed that for economic reasons two types of gasoline-driven rail-car should be standardized. The first unit would be of approximately 60-hp. capacity and would use gasoline as fuel. The second unit would be of 300-hp. capacity and would use the type of fuel suited to Diesel engines. Mr. Wanamaker agreed with the conclusions reached in Mr. McGrew's paper that the use of standardized commercial engines of limited horsepower, but installed in multiples in a given rail-car, is a most satisfactory system. Engines, clutches and transmissions of this size have been developed to a highly satisfactory degree for the heaviest and hardest truck service. With the intelligent mounting of these engines and units on a rail-car, together with a suitable and satisfactory multiple-unit control, the successful solution of the rail-car problem for all except the heavier class of service is offered. The 300-hp. unit suggested by Mr. Wanamaker would differ radically from the 60-hp. unit. It would be driven by the latest type four-cycle multi-cylinder Diesel engine. The engine speed should not exceed 650 r.p.m. It should use a system of fuel injection and distribution that would eliminate high-pressure air-piping, the spray air-bottle and similar parts. This engine should operate at a constant speed and depend upon a means of electrical transmission to satisfy the variable torque and speed requirements of the locomotive. The 300-hp. unit would be intended primarily for locomotive use. Flexibility as regards the capacity of the locomotive could best be secured by using any desired number of generators and motors in multiple in one or more locomotives.

Salient Points Raised in Discussion

In the general discussion following these papers, J. P. St. Clair, engineer of car construction of the Atchison, Topeka & Santa Fe Railroad Co., said that he recognized the field for gasoline-driven cars. The first requisite would be reliability of the motive power. Charles Ripley, general mechanical engineer of the Santa Fe Railroad, said that the Western railroads would require units of increased capacity. They must have something that will solve the mixed-train problem. Men in charge of railroad traffic will not be satisfied with having the gasoline rail-car handle passenger traffic only. The cars must have sufficient capacities to eliminate entirely steam operation on the branch lines. A. M. Russell, vice-president of the Sykes Co., said that automobile engineers must remember that they are building for railroad service and that their equipment will be operated by railroad men. He said that greater cooperation must be had between the automotive and the railroad engineers when this type of equipment is being developed. It was his opinion that engines and transmissions should be altered to suit the present-day railroad equipment rather than expecting radical changes to be made in railroad cars and trucks to adapt them to automotive practice.

TRAFFIC HEAD CRITICISES HEAD-LAMPS

Road Illumination and Light Racing-Car Design Are Minneapolis Subjects

Poor focusing adjustments, poor lenses, lack of bracket-adjustment provisions and improper construction of the lamp itself are outstanding defects of head-lamps, particularly on medium-priced and cheaper grades of car, according to the findings of the Traffic Committee Safety Bureau of the Civic and Commerce Commission of Minneapolis. This statement was made by Dr. H. F. Marston, chairman of the Committee, in his address on the Head-Lamp Problem in Minnesota, delivered at the Minneapolis Section meeting held on April 2. He said also that the head-lamps found ordinarily on cars constitute the "cheapest" equipment of the automobile of today.

Among other defects discovered by the Committee, extremely numerous instances of rotating and partly rotated lenses were cited, and it was found that many head-lamps had no provision for holding a lens in its one proper position. Evidently careless assembly that surely needs to be eliminated resulted in failure to center the filament of lamp-bulbs properly, and it was not unusual to find a bulb that would cause a difference of 3 to 10 ft. in the height of the beam on the 200-ft. testing-board, when the bulb was turned half-way around in its socket. Replacement of a properly adjusted burnt-out bulb by a bulb having a filament improperly installed would then cause the head-lamp to be wrongly adjusted as to height of beam.

Doctor Marston's opinion is that head-lamps should be made waterproof; also, that they should be ventilated better. Head-lamps that "sweat," due to temperature changes, were noted. He said that the Minnesota head-lamp laws are not satisfactory, and that engineers who design and supervise the construction of lamps, lenses, bulbs, mechanical focusing-devices and brackets or supporting structures for the head-lamp itself can greatly improve conditions.

Casualty Prevention

Deprivation of the driving privilege, regardless of what a driver's financial standing may be, has been found to be the most effective weapon against reckless driving, and to deprive a driver of using his steering-wheel for a period depending for its length upon the severity of his offense has been the most effective punishment. The Committee desires a license law that will label every driver of an automobile, and a clause in the law that automatically will deprive a driver of his privilege to drive upon conviction in an authorized court.

In fully three-quarters of the cities of our Country, teaching children of the public schools the means of safety has been tried and proved successful. Within 1 year, in Detroit, 97 children were killed outright by motor vehicles, but the next year after adopting safety teaching to public school children, the number of deaths of children from this cause was reduced to 36.

Following Doctor Marston's address, traffic conditions in Minneapolis were generally discussed and several prominent members participated.

Light Racing-Car Design

Speaking for J. L. Larson, of the Owen Motor Co., St. Paul, who was unable to be present because of illness, his associate, E. L. Carson, said that Mr. Larson was asked to make tests to determine what power, speed and endurance could be obtained from a standard block engine in connection with his construction of a safe racing car, had used a Ford engine and had made the following changes.

An overhead eight-valve cylinder-head was made, since the Ford cylinder-block, which is of L-head design, is not conducive to extreme power and speed attainment, and the compression pressure was approximately 85 lb. per sq. in. The cylinder bores were ground to be 0.015 in. oversize and were fitted with split-skirt type aluminum-alloy pistons. The standard crankshaft was replaced with a drop-forged coun-

Schedule of Sections Meetings

MAY

2—Washington Section—Traffic and Traffic Accidents

7—Milwaukee Section—Fuels—Thomas Midgley, Jr.

8—Detroit Section—Fabric Bodies—K. L. Childs
Window Lifters—S. W. Nicholson

Minneapolis Section—Symposium on Engineering Progress in Farm Implements, Aircraft and Automobiles

9—Mid-West Section—Fuels—Thomas Midgley, Jr.; Golf at Hammond Country Club in morning; Inspection of Whiting Refineries of Standard Oil Co. in afternoon

13—Pennsylvania Section—Motorbus Design and Operation—A. E. Hutt

15—Metropolitan Section—Repainting—Dr. A. H. Sabin, L. B. Pulsifer, E. M. Flaherty and O. H. Briggs

22—Detroit Section—How Can the Engineer Help to Solve Service Problems?—H. N. Davock, O. E. Hunt and W. T. Fishleigh

terbalanced crankshaft drilled for a pressure oiling-system, and the flywheel changed to one made of steel and 18 lb. lighter than standard. The planetary transmission was checked carefully for alignment and balance. A German-made magneto provided ignition and carburetion was through a carefully cast intake-manifold that carried a 1¼-in. plain-tube carbureter. The result was a speed increase up to 3400 r.p.m., with the greatest torque at about 2600 r.p.m., and 32 hp. developed. A car speed of 87 m.p.h. was attained easily. However, the car was again remodeled.

A three-bearing and a five-bearing crankshaft were each machined from solid steel-billets, drilled for oil pressure-lubrication and balanced scientifically. A smaller flywheel was used and the reverse-gear was removed from the transmission. The five-bearing crankshaft proved far superior and was retained. Aluminum-alloy connecting-rods that weigh only 12 oz. each, complete, were made and used. The most important change was the boring out of the cylinders down to the water-jacket to an inside diameter of 3.016 in., giving the engine a 122-cu. in. piston-displacement. Two 1½-in. carbureters replaced the single 1¼-in. carbureter, and the compression-ratio was increased to be 7½ to 1. The resultant engine speed was 4600 r.p.m. and 41.9 hp. was obtained. Many questions regarding details of these changes and their specific effects were asked and answered.

MILWAUKEE SECTION ACTIVITIES

C. W. Pendock assumed the risks of a prophet at the Milwaukee Section meeting on April 2, and read a paper on the Future Passenger-Car. Following this, C. T. Myers gave a brief illustrated talk on chassis lubrication.

The Milwaukee Section will be addressed by Thomas Midgley, Jr., on the evening of May 7 at City Club, Second Street and Grand Avenue, Milwaukee. He will cover the topic of Automotive Fuels and Their Detonating Characteristics.

BETTER STEERING AND HEAD-LIGHTING

Engineering Improvements for Steering-Systems and an Anti-Glare Symposium

F. F. CHANDLER

Steering-system effectiveness and possible improvement of the engineering details of motor-vehicle steering-systems were the subjects selected for pertinent query by F. F. Chandler, chief engineer of the Ross Gear & Tool Co., Lafayette, Ind., in the paper that he presented at the meeting of the Indiana Section held on April 3 at the Hotel Severin, Indianapolis. He characterized the steering-system as being the whole bag of tricks, from the steering-wheel clear on down through the steering-gear, linkage and the like, to the front wheels; and said that the steering-gear is simply a reduction mechanism and nothing else.

Lack of development in steering-systems is due largely to the fact that the conventional steering-system layout used generally has operated with a reasonable degree of satisfaction. In the main, the driving public has believed that motor-vehicle steering is satisfactory because it has not been conscious that easier steering is obtainable. Some manufacturers have made conscientious and successful efforts toward attaining improved steering ability and some of the parts makers have aided, but Mr. Chandler believes that no one has yet undertaken the engineering research work on steering-systems that is needed to accomplish basic improvement in them for the industry as a whole. So far as he knows, no one at present has any knowledge of the live stresses in steering-systems while the vehicle is in motion. He argues that steering-system design would produce safer steering-systems and could be prosecuted with greater confidence if data relating to steering forces in action while the vehicle actually travels over roads of all kinds were obtained.

Steering-systems have developed thus far largely due to circumstances; if some part broke, it was made larger the next time to give it added strength but this has worked against the attainment of easy steering, which includes a comfortable sitting position for the driver, convenient location of the controls that must be handled frequently and peace of mind relative to steering accuracy and dependability; and comfort while steering is an important item that, from now on, must be given very careful consideration in automobile design.

Assisted by H. A. Huebotter, research assistant of the engineering experiment station at Purdue University, Mr. Chandler is developing automatic recording instruments that, if successful, will produce graphic records of the physical effort necessary to drive an automobile and record simultaneously the forces and shocks imposed upon the entire steering-system. What he hopes to produce is a set of portable instruments that can be used to obtain accurate records from automobiles and trucks and, if the instruments can be made sufficiently sensitive, to use them to obtain data regarding such matters as the force needed to steer a car equipped with balloon tires as compared with that required for one having standard tires, whether the application of brakes to all four wheels makes steering harder and the like.

STEERING-GEAR DESIGN-FUNDAMENTALS

A most important and yet most neglected part of a steering-system is the steering-gear, and the two fundamentals of steering-gear design are (*a*) to secure the needed mechanical advantages so that the driver has sufficient leverage to handle the vehicle and (*b*) to accomplish this within a reasonable amount of turning movement of the steering-wheel. Unfortunately, these requirements conflict, since great mechanical advantage can be secured only by increasing the angular movement of the steering-wheel beyond a reasonable amount.

Angular movement of the steering-arm or drop-arm varies usually from 65 to 75 deg. and ordinarily it is sufficient to produce the necessary horizontal movement of the drag-link to obtain the desired turning effect. Conventional practice also limits the steering-wheel movement from about 1½ to 2½ turns, and it is desirable to keep the number of steering-wheel turns as small as possible. These overall angular ratios have been used in varied types of mechanism, such ratio being the product of the helix ratio and the inward ratio. When this ratio is multiplied by the quotient obtained after dividing the radius of the steering-wheel by the length of the steering-arm, the product represents the overall mechanical advantage. This is lessened by the friction in the steering-gear; so, it is desirable to reduce this friction as much as possible.

Overall angular ratios of steering-gears have ranged between 7 to 1 and 9 to 1. Ordinarily, they have been sufficient to enable the driver to operate the vehicles as built, but the mechanical advantage has been increased very little to compensate for the increased weight of vehicle, and this is the basic reason that large vehicles are difficult and tiresome to steer. Further impediments to easy steering have appeared with the coming of the balloon tire and four-wheel brakes, making it necessary for builders to pay more attention to the overall angular ratios of steering-gears; so, the ratio recently has been increased to be 12 to 1 and this, in many cases, is not more than sufficient to control the total steering-forces. In addition to the greatly increased inertia forces in large cars operating at high speed, and the very much greater frictional resistance to steering, a time element also must be considered. Unfortunately, if a steering-gear of great mechanical advantage is used to enable a

driver to handle a car easily, it reduces his ability to cause the car to dodge an obstacle quickly because the steering-wheel must be moved so much farther in proportion to produce the necessary angular movement of the front wheels.

Steering-Gear Improvement

Successful efforts have been made to lessen the overall friction of the steering-system so that easier steering would result, but the overall efficiency has been increased so greatly that road shocks wear a driver out on long drives. Although the steering-gear wear is very much less, theoretically, on a steering-gear that has this amount of reversibility, the shocks that otherwise would be absorbed by the mechanism are transmitted to the driver.

Stating that the balloon-tire manufacturers are now frank to admit that these tires steer harder than standard tires. Mr. Chandler also voiced his belief that four-wheel-brake cars are likewise, in practice, harder to steer. He says that the two extremes of eliminating road-shocks are (*a*) to use a reversible steering-gear and enough other friction all along the line to dampen such shocks or (*b*) to use an irreversible gear and eliminate friction as much as possible.

Classifying steering-gears as (*a*) the bevel gear and segment, (*b*) the worm and wheel, (*c*) the screw and nut, (*d*) the split nut and (*e*) the cam and lever types, Mr. Chandler said classes (*b*) to (*e*) are all dependent upon the helix for actuation. As to helix characteristics, the input work is delivered by a helix or thread and the output work is taken from a driven wheel or sector; from a nut, sometimes a split nut; from a rocker-lever on a shaft; or from a lever on a shaft, for types (*b*) to (*e*).

Efficiency, output divided by input, depends very largely upon the efficiency characteristics of the helix itself and helix efficiencies developed by well-known authorities are shown in Fig. 1. Curves 1 and 2 are for a screw alone in which the coefficient of friction, f, = 0.05 and 0.10 respectively. Curves 3 and 4 are for a screw and collar thrust in which f = 0.10 and 0.15 respectively. The curves are theoretical and simply serve to show approximately where the coefficient of friction lies. All tests were made with a 50-lb. load on an 8-in. steering-arm. None of the worm and wheel or split-nut types were reversible with the load. The cam and lever types were not reversible in center-driving, but were all reversible in the extreme positions. All cam and lever gears had ball thrust and radial bearings. The worm and wheel type having the greater helix, the results of which are not shown in Fig. 1, was reversible with heavier loads.

Points in Group *A*, Fig. 1, are for the cam and lever type in the center-driving position. Group *B* shows points for the cam and lever type in extreme positions; three curves were plotted, each with a different helix angle in extreme positions. Group *C* points are for worm and wheel gears having ratios varying between 7 to 1 and 9 to 1, with varied helix angles; all had ball thrust bearings. The point shown as Group *D* represents the average efficiency of a split-nut type of gear.

Fig. 1 shows that a helix angle of say 20 deg. is very much more efficient than one of say 10 deg. Hence, if a steering-gear can be produced that has a helix angle of say 10 deg. in mid-position, with comparatively low efficiency, and also a helix angle of say 20 deg. in either right or left extreme positions, with very much greater efficiency, this is very desirable. Mr. Chandler then discussed the development of a variable ratio to secure such a result.

In obtaining the groups of points shown in Fig. 1, a complete steering-gear was used in connection with two drums, each 2 ft. in diameter; one drum was substituted for the usual steering-wheel and the other drum for the usual steering-arm. Then, certain dials were used to determine the overall angular-ratio between the movement of the steering-wheel and that of the steering-arm. By applying certain loads on the drum representing the steering-arm, these being equal to the equivalent pressures on the steering-ball of the steering-arm, the weight needed at the periphery of the drum representing the steering-wheel to lift the weight on the steering-arm was determined.

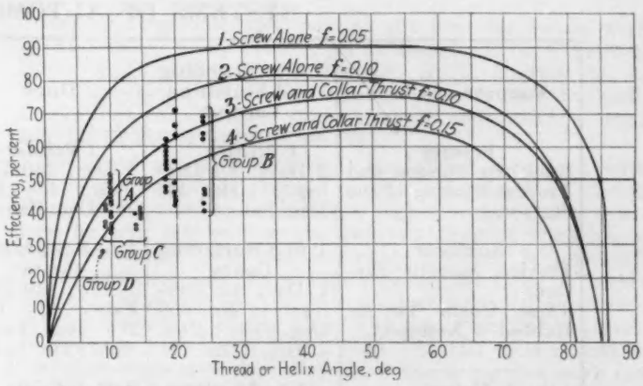


Fig. 1—Efficiency Characteristics of the Helix Itself

Curves 1 and 2 Are for a Screw Alone in Which the Coefficient of Friction Equals 0.05 and 0.10 Respectively. Curves 3 and 4 Are for a Screw and Collar Thrust in Which f Equals 0.10 and 0.15 Respectively. All Tests Were Made with a 50-Lb. Load on an 8-In. Steering-Arm. Points in Group *A* Are for the Cam and Lever Type in the Center-Driving Position. Group *B* Shows Points for the Cam and Lever Type in Extreme Positions. Group *C* Points Are for Worm and Wheel Gears Having Ratios Varying Between 7 to 1 and 9 to 1, with Varied Helix Angles. The Point Shown as Group *D* Represents the Average Efficiency of a Split-Nut Type of Gear

Important factors concerning anti-glare of head-lamps were discussed by several prominent speakers, their remarks at this meeting constituting a symposium on the subject.

CAUSES OF PAINT FAILURES

General Motors Investigation Places Blame on Poor Color and Rubbing Materials

Important conclusions with reference to automobile painting systems and paint durability which are the results of investigations carried on in the laboratories of the General Motors Research Corporation were set forth in a valuable paper presented by H. C. Mougey before the Buffalo Section on April 28. These particular investigations were concerned with the conventional methods of enameling and painting rather than with the pyroxylin and newer finishes. Based on the results, means have been found for materially increasing the life of paint and varnish in combination, but the resulting durability cannot match that of the asphaltum and pyroxylin enamels.

Opening his talk with a brief survey of the various painting materials and their properties, Mr. Mougey led up to the results of many hundreds of exposure tests of different paint and varnish combinations. In the conduct of these tests, small standard panels are painted to the trial specifications and these are exposed to the weather by laying them in racks on the roof of the laboratories. These test panels are examined periodically and photomicrographic records are made of their condition from time to time.

Seasonal Conditions Affect Test Results

One of these investigations showed that the length of life of varnishes depends greatly upon the time of the year when the test panels are exposed. Curves exhibited by Mr. Mougey showed the truth of this statement in impressive fashion. Using an ordinary finish-varnish, panels exposed during the months of June, July and August showed an average life of 100 days. On the other hand, exactly similar panels exposed in the months of October and November showed an average life of 275 days. This great difference in life is attributable to the higher temperature of the atmosphere and the longer hours of sunshine in midsummer as compared with the fall and winter.

To locate the causes of the poor durability of ordinary automobile finishes, test panels were prepared in lapcoats, and it was found that the primer and surfacing coats were very durable, even if unprotected with additional coats. It was also found that the durability of the color, rubbing and finishing coats applied over surfacing coats was the

SYSTEMS OF AUTOMOBILE BODY FINISHING

Purpose of Coats	Color, Rubbing and Finishing Varnish	Duco	Low Bake Body Enamel	Color Enamel	High Bake Enamel
Primer Stick To Surface and Prevent Rusting of the Surface.	**1 Primer** 2 Days, Air Drying; 1½ Hr., 300 Deg. Fahr.	**1 Primer** 1 Day, 140 Deg. Fahr.; 1½ Hr., 275 Deg. Fahr.	**1 Primer** 1 1-3 Hr., 350 Deg. Fahr.	**1 Primer** 1 1-3 Hr., 350 Deg. Fahr.	**1 Primer** ½ Hr., 450 Deg. Fahr.
Surfacer Provide Smooth Surface. These Coats To Be Rubbed if Necessary.	**1 to 8 Surfacing Coats** 1 Day, Air Drying; 1½ Hr., 300 Deg. Fahr.; Rub, 3 Hr. ½ Hr.	**1 to 8 Surfacing Coats** 1 Day, 140 Deg. Fahr.; 1½ Hr., 275 Deg. Fahr.; Rub, 3 Hr. ½ Hr.	**No Surfacing Coats Required.** No Rubbing Required.	**No Surfacing Coats Required.** No Rubbing Required.	**No Surfacing Coats Required.** No Rubbing Required.
Color Desired Color. Smooth Surface. These Coats To Be Rubbed if Necessary.	**1 to 5 Color Coats** 2 Days, Air Drying: 1½ Hr., 250 Deg. Fahr.; Rub., 3 Hr. 1 Hr.	**2 to 4 Coats of Duco** 1 Day, Air Drying; ¼ Hr., Air Drying; 1 Hr., 150 Deg. Fahr.; Rub and Polish 2 to 4 Hr.	**1 Coat** 1 1-3 Hr., 350 Deg. Fahr. No Rubbing Required.	**1 Coat** 1 1-3 Hr., 350 Deg. Fahr. Light Rubbing Desired.	**1 Coat** ½ Hr., 450 Deg. Fahr. No Rubbing Required.
Finishing Luster and Protection of Undercoats.	**1 to 2 Finishing Coats** 5 Days, Air Drying; 1 Day, Air Drying.	**No Finishing Varnish Required. May Be Used if Desired.**	**1 Finishing Coat** 1 1-3 Hr., 350 Deg. Fahr.	**1 Finishing Coat** 2 Hr., 250 Deg. Fahr.	**1 Finishing Coat** ½ Hr., 450 Deg. Fahr.

All the purposes are to be fulfilled at as low a cost of labor, time and material as possible, and the durability of the finish is to be as great as possible.

same as when they were applied over bare metal, thus showing that the primer and surfacing coats were both durable in themselves and satisfactory as a foundation for the other coats. However, the color and rubbing-varnishes were very low in durability, failing in from 1 to 5 weeks when exposed unprotected by finishing-varnish. The finishing-varnish is supposed to protect the color and rubbing-varnishes of low durability, but the task is too great and the real reason for the short life of the ordinary automobile finish is the failure of the color and rubbing-varnishes, which as they crack, take the finish-varnish along with them.

When a finishing-varnish is applied over color and rubbing-varnishes of low durability it is apparent that if the finishing-varnish should be removed in spots due to scratches from dust in cleaning the car or by any other mechanical injury, the color and rubbing-varnishes would be exposed without any protection at these spots, and if the color and rubbing-varnishes will fail in a very short time when unprotected, failures will start at these scratches. This actually does happen in service as the General Motors investigations have shown.

Effect of Undercoats on Finishing-Varnish

A number of finishing-varnishes were tested by applying them over a number of different color and rubbing-varnishes. These panels were prepared with the finishing-varnish over only half of the panel so that the durability of the unprotected color and rubbing-varnishes could be observed. The results of this test showed a marked tendency toward increased durability of the finishing-varnish with an increase in the durability of the color and rubbing-varnishes, but this is only true when the finishing-varnish is sufficiently durable to profit by the durability of the color and rubbing-varnishes. In addition to showing that the maximum durability is obtained by using a very durable finishing-varnish over durable undercoats, several other facts are illustrated by these tests as follows:

(1) The finishing-varnish should be more elastic than the undercoats

(2) Over color and rubbing-varnishes low in durability, a medium-grade finishing-varnish that dries to a hard film may give better results than a more durable finishing-varnish that is more elastic and does not dry so hard

(3) Best results cannot be obtained with a poor finishing-varnish, regardless of the undercoats

The conclusions to be drawn from these tests are that to improve the durability of automobile finishes it is necessary to use very durable color and rubbing-varnishes, with a top coat of the most durable finishing-varnish. Although the first cracking of finishing-varnish is postponed by applying it over a durable undercoat, unless these undercoats are of the proper elasticity, the finishing-varnish may fail very quickly after it once starts to crack.

Mr. Mougey gave a brief description of the pyroxylin enamels that are now being used. He also discussed so-called "color enamels" that are made by grinding colors in durable clear varnish. He said that this latter system has considerable promise for the future. Mention was also made of the system that attempts to obtain durability by using color coats having a very high durability and then eliminating the finishing-varnish entirely.

Rubber Paints Are Future Possibility

Mr. Mougey said that considerable work had been done on the use of phenolic-condensation products, but although remarkable results have been obtained, the commercial use of such material for finishing automobiles has not been worked out. For many years the most durable coating for artificial leather has been made from rubber, and finishes made from rubber for automobile bodies are now being developed by several large companies. In conclusion, Mr. Mougey gave the opinion that the recent stimulus given paint investigation by the introduction of pyroxylin enamels will result in materially lengthening the life of automobile finishes.

CLEVELAND SECTION'S RADIO NIGHT

Radio apparatus, the mode of transmittal and receipt of wireless communications and broadcasting methods were explained to more than 400 members and guests of the Cleveland Section by a representative of the Radio-Vox Co., Cleveland, at the meeting held on April 21. Interesting as this was, and well received, the audience was more demonstrative while E. S. Jordan, president of the Jordan Motor

Car Co., was delivering his talk on Why Henry Ford Would Not Run for President, and punctuated the discourse with applause and laughter to indicate its warm approval. Incidentally, the speech was heard via wireless by members of the Metropolitan Section in New York City.

By courtesy of the National Electric Lamp Association, a moving picture showing what takes place inside a wireless tube when it is in action was exhibited, and the film was run a second time to make certain that all might see it. Opportunity was also afforded those in attendance to see the showrooms and the studios at Nela Park, to listen to the special concert arranged by the Willard Storage Battery Co., and to partake of light refreshments.

Thus the members and guests, their wives and children, were instructed and entertained, formed new acquaintanceships and came to know each other better. Their evident enjoyment of the evening's privileges is perhaps the most satisfying thanks that can be accorded John Younger, the speakers, the Nela Park organization and the Willard Storage Battery Co., whose combined efforts made the meeting a success.

MIDGLEY ADDRESSES DAYTON SECTION

Thomas Midgley, Jr., repeated his Annual Meeting paper on Radiation Characteristics of the Internal-Combustion Engine before the meeting of the Dayton Section on April 15. This paper was printed on p. 182 of the February issue of THE JOURNAL.

NEW ENGLAND DISCUSSES LUBRICATION

Chassis lubrication formed the subject of an interesting meeting of the New England Section in Boston on April 15. F. H. Gleason read the paper of the evening, which described a reservoir system of centralized chassis lubrication. Mr. Gleason's paper appeared on p. 422 of the April issue of THE JOURNAL.

FLEET MAINTENANCE AND OVERHAUL

Suggestions for Servicing Motor Trucks and Decreasing Breakdowns

JOHN F. WINCHESTER

Before an unusually large and appreciative gathering of members and guests of the Metropolitan Section, at its monthly meeting at the Automobile Club of America, New York City, on Thursday, April 17, J. F. Winchester, supervisor of motor equipment, Standard Oil Co., outlined some of his experiences in maintaining and overhauling motor trucks on a large scale. His paper, which is printed on p. 496 of this issue of THE JOURNAL, was entitled Observations of a Superintendent of Motor-Truck Fleet Operation. The interest aroused in this subject was evidenced by the number of persons who took part in the discussion and by the completeness of the written discussions submitted by those who were unable to be present. These included contributions from G. R. Gwynne, chief automotive engineer, Continental Oil Co., Denver, Colo.; F. C. Fiechter, the Wanamaker Garage, Philadelphia; A. B. Tilt, automotive department, Swift & Co., Chicago; F. A. Whitten, General Motors Truck Co., Pontiac, Mich.; J. E. McLaughlin, Eleto Co., New York City; F. K. Glynn, engineer of motor vehicles, New York Telephone Co.; and A. Schindel, superintendent, L. Bamberger & Co., Newark, N. J.

Among those who took part in the oral discussion were B. K. Rhodes, R. E. Fielder, M. C. Horine, R. E. Plimpton, Capt. W. S. Miller, H. W. Slauson, W. G. Hawley, M. R. Van Benschoten, Ward La France and Colonel Stillwell. Limitations of available space prevent more than a brief mention of the suggestions offered.

In a written communication, Mr. Glynn concurred with Mr. Winchester with regard to the advantage of having only a small number of different makes of truck; his practice, he said, had been to use only two kinds of truck above 1-ton capacity. Only one avoidable accident is tolerated. If an operator has more than one accident, he is either dropped from the roll or given other work. He believed that only minor repairs should be made in the field; all others should be made in the shop. Special tools should be designed when nothing satisfactory for doing the work can be obtained. In his shop a manually operated machine for repairing skid chains has been designed that will remove and replace the entire set of cross links in 8 min.

Mr. Winchester's statement that no given time or mileage can be assigned to a vehicle, wrote Mr. Gwynne, would not be practicable in country such as that in which his company was operating, where motor trucks are located at outlying stations 500 to 600 miles from the nearest base shop. A minimum mileage before being sent to the shop for repairing is placed on all equipment: 15,000 from any passenger car, 20,000 from any 2-ton motor truck, 25,000 from any 1-ton motor truck and 50,000 from any 3.5-ton motor truck operating under city conditions. After the minimum mileage has been reached by a truck another piece of equipment of the same description is shipped from the base station to the special station, releasing the unit to be repaired, which is shipped to the nearest shop for reconstruction. Indifferent overhauling cannot be tolerated and the reconstructed vehicle must be as perfect mechanically as the original truck. Under geographical conditions such as those mentioned the unit system of repairs is not satisfactory, for the new unit unbalances the rest of the structure. No repair parts are stocked, notwithstanding the fact that in some cases the nearest parts shop is from 400 to 1200 miles distant. The same mechanical difficulties are developed in trucks, no matter what may be the conditions under which they operate. A standard nomenclature of parts would be of great assistance in ordering and purchasing parts, for the ordering of parts is the greatest burden that operators have to carry.

Mr. Whitten explained in a written communication that the greatest difficulty the engineering departments of truck building companies have is in the inadequacy of service records and information. Those from one station cannot be compared with those from another. If records were kept and inspected from week to week, fuel and oil consumption could probably be reduced from 30 to 50 per cent. Every detail of the truck is a compromise, finally, of accessibility, cost of repair parts, manufacturing methods and first cost. If every suggestion were adopted, manufacturing on a large scale would be impossible and the price of the vehicle would be so high that it could not be sold in competition. Making a very small change sometimes means complicated changes in tool equipment.

Mr. Tilt expressed the opinion that too many variable facts prevail in different lines of the industry to make comparison possible but certain items of the cost of trucks, such as the cost of tires, gasoline, oil consumption and repair expense, should be comparable in every line of business. To determine the depreciation of trucks, the records are gone over from day to day to get the actual depreciation in time and money of trucks of different capacity. Straight-line depreciation is unfair, for the better class of equipment naturally has a longer life than medium-priced or cheap equipment.

Mr. Fiechter believed that the best possible results in economy and in the speed of making repairs could be obtained by the unit-repair system. Break-downs in service can be reduced to a minimum only by taking vehicles out of service for inspection and repairs. In 10 per cent of

his company's equipment this cannot be done, but in such cases a time limit is set within which all trucks shall be inspected and the necessary repairs made. The territory covered and the class of service govern tire equipment. Solid tires should not be used in handling fragile material or on high-speed equipment and pneumatic tires should not be used on broken roads or with heavy loads. High-grade cushion tires have a field of operation that many truck owners have failed to observe. The accident hazard would be reduced by a very large percentage if cars were equipped with enclosed brakes, which would give better braking and increase the life of the lining. Standardization of body construction will solve the cab problem. Governors on trucks will continue as accessories until the speed laws are more rigidly enforced or legislation is brought about compelling all trucks to be equipped with governors.

The business of the Eleto Co., said Mr. McLaughlin, is a combined delivery for department stores. The equipment consists of both electric and gasoline trucks. Anything more than the adjustment or the installing of minor parts should be done in a central maintenance station. Bringing all chassis lubrication connections outside would not be practicable, as some parts rotate and would snap off as soon as the vehicle started. Enclosed brakes are an excellent idea but would not allow so free cooling and some types of rear-wheel service brake would be very difficult to enclose. To get the best results from a vehicle it should be handled by the same operator and under the same topographical conditions. When the unit system of repairs is adopted, and previously used and repaired parts are installed in other vehicles, breakdowns frequently occur.

Replying to points brought out in the oral discussion, Mr. Winchester said that many cheap vehicles, because of poor inspection, have to be overhauled before they are sent out for the first time; that even after overhauling occasional failures occur; they need time to limber up. Serious damages, he said, were not charged to the capital account but to running repairs; when the amount is large it is charged to a special fund minus what is considered a fair allowance for the time that the vehicle has been in service.

Records of miles per gallon have been discontinued. A check is kept on the operators by the sales manager who keeps a record of the stock on hand. He checks the fuel consumption from the garage record. He believed in putting quality into vehicles. The best grades of material and workmanship will enable the truck to operate continually and to keep out of the shop. On vehicles that had air shock-absorbers the operation cost and the repair cost had been lower and the tire life longer. One reason he had got away from them was the exceptional use he had obtained from cushion tires.

THE SUMMER MEETING APPROACHES

Attractive Program Arranged for Members Who Migrate to Spring Lake in June

Soon after this issue of THE JOURNAL reaches the members they will receive the special issue of the *Meetings Bulletin* making formal announcement of the Summer Meeting at Spring Lake, N. J. With this Bulletin will be included the application blanks to be used for making hotel reservations. Rates are the same as those in effect last year and range from $8 to $13.50 per person per day, including all meals.

The meeting will open with luncheon on Tuesday, June 24, and will close after dinner Friday evening, June 27. The intervening 4-day period will be crowded with a medley of professional, recreational and social activities. Seven meetings are scheduled, each of which will be devoted to engineering topics of vital interest to all progressive automotive engineers. Golf, tennis, trapshooting and baseball tournaments are scheduled; the annual field day and swimming carnival will hold the stage for two afternoons; there will be other recreational events of a character so varied and comprehensive as to include everyone's hobby. Summer meet-

NATIONAL MEETINGS CALENDAR

AUTOMOTIVE SERVICE MEETING AND MAINTENANCE EQUIPMENT SHOW
Detroit—May 19-22

SUMMER MEETING
Spring Lake, N. J.—June 24-27

AUTOMOTIVE TRANSPORTATION MEETING
New York City—Sept. 24-25

AERONAUTIC MEETING
Dayton—Oct. 2

PRODUCTION MEETING
Detroit—Oct. 22-24

SERVICE ENGINEERING MEETING
Cleveland—Nov. 18-19

MOTORBOAT MEETING
New York City—Jan. 7, 1925

ANNUAL DINNER
New York City—Jan. 8, 1925

ANNUAL MEETING
Detroit—Jan. 20-23, 1925

THE CARNIVAL
Detroit—Jan. 21, 1925

ings have established a reputation for tip-top social diversion and the 1924 Meeting will be no exception. Card parties, dances, movies on the lawn and numerous other features will be provided for the fair-sex. Even the juggler of Chinese tile will be happy, for Mah-Jong is scheduled at Spring Lake.

The Technical Program

As announced in previous issues of The Journal, four subjects of current interest will be covered in the Summer Meeting sessions; these are crankcase-oil dilution, air-cleaners, new developments in transmissions and riding-quality. In addition to these sessions there will be the meeting of the Standards Committee and the Semi-Annual Meeting of the Society. The schedule of professional activities follows:

Tuesday Afternoon	—	Riding-Quality Session
Tuesday Evening	—	Semi-Annual Meeting
Wednesday Morning	—	Oil Dilution Session
Wednesday Evening	—	Oil Dilution Session
Thursday Morning	—	Standards Committee Meeting
Thursday Evening	—	Air-Cleaner Session
Friday Morning	—	Transmission Session

While the technical program is not completed definitely, some of the details can be announced at this time. In the Riding-Quality Session, papers will be given by S. P. Hess, of the Detroit Steel Products Co.; Prof. E. H. Lockwood, of Yale University; J. A. C. Warner, of the Society's Research Department and others. Neil MacCoull, of the Texas Co.,; A. Ludlow Clayden, of the Sun Oil Co.; Ralph H. Skinner, of the Skinner Automotive Devices Co.; a member of the Bureau of Standards' staff and others will read papers in the two Dilution Sessions. Air-cleaners will be discussed in papers by A. H. Hoffman, of the University of California; L. L. Dollinger, of the Staynew Filter Co.; A. R. Squyer, of the Holt Mfg. Co.; P. S. Tice, of the Stewart-Warner Speedometer Corporation and others. The Transmission Session will include papers by G. W. Cate, of the Flexo-Motive Corporation; W. A. McCarrol, Prof. J. M. Nickelsen, of the University of Michigan, and a representative of the Weiss Engineering Association.

Following the successful practice pursued at past Summer Meetings, provision will be made for the exhibition and demonstration of devices and equipment that bears close relation to the subjects covered in the technical program. The Meetings Committee will not permit the exhibition of any other equipment nor will it tolerate commercial solicitation on the part of anyone during the period of the meeting.

Reduced Railroad Fares and Special Trains

Practically all of the members who will attend the Summer Meeting can purchase railroad transportation to Spring Lake at reduced rates. At some future date every member will receive a reduced-fare certificate that entitles the holder to buy round-trip tickets to Spring Lake for fare and a half.

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The Essex and Sussex Hotel, Spring Lake, N. J.

Of course, this privilege is limited strictly to members of the Society and their families. Certificates presented by non-members will not be honored at Spring Lake by the railroad authorities.

The special train service from the Middle-West will be unusually fine for this year's Summer Meeting. All trains will be routed over the New York Central Lines and the equipment will be of the finest. This is the ideal way to travel to the meeting since it will be possible to go direct to Spring Lake from your home town without change. One of the two S.A.E. Specials will originate at Cleveland and the other at Detroit. The Cleveland train will connect with the regular trains from Ohio and Indiana points. The Detroit train will bring the Chicago and Michigan contingents. Both trains will pass through Buffalo, Rochester and Syracuse and will leave the main line at Utica, coming down the west bank of the Hudson River over the tracks of the West Shore Railroad. This will add a touch of novelty to the trip for it will give the members an opportunity to view the scenic eastern shore of the Hudson River.

Even more important than the going service is the excellent service returning West. This eliminates the cause of the only serious complaint made about the 1923 Summer Meeting. The S.A.E. Western Special will leave Spring Lake after dinner on Friday evening and return all of the members to their homes before Saturday night. Since Spring Lake operates on daylight saving time, the leaving time is virtually 8 o'clock, so that plenty of time is allowed to enjoy the Friday sports, pack up, dine at the hotel and catch the train in comfort.

THE TRACTOR MEETING

Auditorium Hotel, Chicago, April 24

INDUSTRIAL USES OF THE TRACTOR

Holt Executive Describes Logging, Road-Building, Snow-Removal and Other Operations

Some conception of the fertile market for automotive tractors in industry and in commerce was portrayed impressively at the morning session of the annual Tractor Meeting of the Society in Chicago on April 24. George D. Babcock, manufacturing executive of the Holt Mfg. Co., described with the aid of fascinating and instructive motion pictures some of the more important tasks that are being handled successfully by tractors of the tracklaying type. As an indicaton of the Holt Company's activity in this field of tractor application, it is significant that 98 per cent of its tractor output is sold for other than agricultural uses.

Probably the most important commercial application of tractors has been in the logging work of the lumber industry. Mr. Babcock showed several reels of film depicting the character of this service and demonstrating the tractor's

fitness for it. Beating its own track through virgin forests, trampling upon the underbrush and young saplings in its path, this powerful creation of the automotive engineer penetrates to the innermost sections of the woodland and snakes out the huge logs to the roads. It seems ironical to call these timber trails roads, for they are only entitled to that name on the basis of their having been cleared of trees and other obstacles. In one film depicting conditions in the Louisiana timber-lands, these forest roads were composed largely of a liquid having the consistency of molasses and seemingly without a bottom. Yet the tractors hauled trains of eight-wheeled trailers through this mire where a dozen oxen were needed to pull one log before the tractors were introduced.

In other instances, the tractors carry on logging operations over snow that is many feet deep. Mr. Babcock called attention to the fact that the pressure under the track in this work is 6.9 lb. per sq. in. whereas a man's foot exerts a pressure of 7 lb. per sq. in. The track shoes are specially designed for this work and have an opening in the center which lets the packed snow push through without damaging the shoes and the track. Track-laying tractors equipped with caterpillar trailers are finding a market in Alaska for the replacement of dog-sleds.

Caterpillar trailers have not been used to any great extent in the logging operations because of their higher first cost. Mr. Babcock believed however that they would prove cheaper in the long run. Some demand is found in the logging field for tractors equipped with winches. In this type of service, the winch cable is paid out to the logs and the latter are then drawn to the tractor, the operation being repeated until a full load has been assembled. One part of the logging film showed a 10-ton tractor hauling a train of 10 sleds, each of which was loaded with over 50 logs, the road in this case being ice-covered. This train load contained 50,000 ft. of lumber weighing over 300 tons.

Tractors in Road-Building

Tractors have been introduced with great success in the construction of highways. Here they are used for removing trees, brush and stumps; for clearing, grading, cutting ditches and hauling all manner of road-building equipment. Films were shown of tractors hauling elevating scrapers and wagons, the scrapers leveling the roadbed and filling the wagons simultaneously. One tractor was shown which had a scraper mounted at its forward end to serve as a bull-dozer for grading and leveling work on dumps or fills. This particular machine was made for the city of Chicago and operates forward and back with equal speed so that it functions somewhat as a planing machine flattening out the uneven surface of the dirt as it is dumped from the wagons.

Another interesting picture showed a new type of road leveling apparatus operated in conjunction with track-laying tractors. In this scheme, steel rails are laid along the sides of the roadbed. These are leveled carefully and serve the same function as the slides of a planing-machine bed. The leveler consists of a long beam traversing the road, supported at the ends by wheels rolling on the guide rails. The beam carries a number of scrapers that resemble small steel snow-plows. This leveler is pulled back and forth over the road surface by the tractor until the earth has been scraped to the proper contour.

The Tractor for Snow Removal

Snow removal from the rural highways of the Country has been an engineering problem of no mean proportions. It is not unlikely that the tractor will prove useful in this work. Mr. Babcock showed motion pictures of a large fleet of tractor-plows operating in New York City and of others clearing country roads. One of the larger rural types pushed a plow before it which incorporated rotating propellers on either side of the plow blades, these propellers throwing the snow to the side of the road as the plow advanced. Snow-plows of this rotor type are still in the development stage and Mr. Babcock expressed the opinion that they should be fitted with a separate source of power for driving the propellers rather than depending upon the tractor engine. It will require 120 hp. to drive these propellers alone and a 10-ton tractor will need all its own power to push the plow through heavy drifts.

Other films showed track-laying tractors in a very severe type of service building dikes along the Missouri River near Omaha. Probably the worst ground conditions existed in the Texas oil fields where the tractors often become mired and have to pull themselves out by a cable and power winch that is fitted on all machines used in this service.

Life of Caterpillar Tracks Being Lengthened

Great interest was shown in the matter of track-life and Mr. Babcock discussed it fully. Many changes have been made in the caterpillar track parts since these were used on military tractors during the war. The Holt engineers have perfected means of heat-treating cast-steel track shoes so that they are confident of their being as uniform as cast-iron shoes. These cast-steel shoes have prolonged the life of the tracks considerably. For plowing or logging service it is not unreasonable to expect a life of 3000 miles on the average. Cases are frequently found where tracks are serviceable for 5000 miles. The Holt engineers are working constantly to perfect the track design and materials so that this latter figure will represent the average life of this rather vulnerable unit.

Oil is recommended as a lubricant for caterpillar tracks when the tractor is operating over dry ground. Grease is very well suited as a lubricant when the going is wet but should never be used in dry service, particularly when the tractor is operating in sand. The problem of sealing the oil into the bearings of the track pins is a difficult one.

Design of Track Shoes and Grouters

A. R. Squyer, of the Holt Mfg. Co., who has spent much time in the field observing the performance of industrial tractors, commented on the various types of grouters or cleats used on the track shoes to secure traction. In the Northern lumber regions, the same tractor is expected to operate satisfactorily over loose snow in the woods and also over frozen roads. This presents a puzzling problem since the two conditions demand totally different grouter characteristics. If the projecting flanges on the grouter are too deep, they will cut below the packed top surface of the soft snow and slippage will result. On the other hand, they must project enough to give traction on the frozen road surface. A satisfactory compromise has finally been effected by making a narrow grouter ⅝ in. high for this class of service. It is arranged so that the ice or frozen road surface immediately behind the grouter face is supported as the latter is withdrawn and lifted, thus preventing any breaking up of the road surface.

Eugene B. Clark, president of the Clark Equipment Co., spoke briefly on small gasoline-propelled tractors for transporting material within manufacturing establishments. He said that the development of units for these machines had been a specialty in itself since no standard automobile engines, transmissions and axles were suited to the purpose. Passenger-car and truck practice had to be practically discarded. His experience and that of the tractor industry in general has shown that success is dependent upon a sound, thorough and high-grade engineering foundation backed by a substantial capital investment. Most failures of tractor companies are traceable to the absence of these fundamentals. Mr. Clark believes that the internal transportation of materials within a factory is fast becoming as important as external transportation.

Mr. Babcock said that materials are transported from machine to machine in the Holt factories on elevating trailers hauled by the Clark type of gasoline tractor. Larger tractors are used in the yards and for the longer hauls.

J. F. Max Patitz, D. P. Davies and others spoke briefly in the discussion. C. M. Eason acted as chairman. In closing the session, he commented on a statement of Mr. Babcock's to the effect that industrial tractors had to be sold by engineers who could analyze the buyer's requirements and fit the tractors to them. Mr. Eason wondered whether the same logic would not commend itself to those in charge of the sale of tractors to the farmer.

GENERAL-PURPOSE FARM TRACTOR

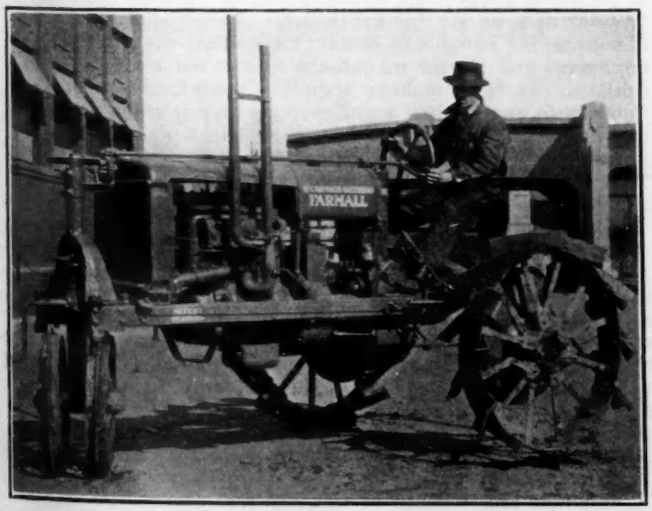
"Farmall" Described by Major Zimmerman of International Harvester Co.

O. B. Zimmerman

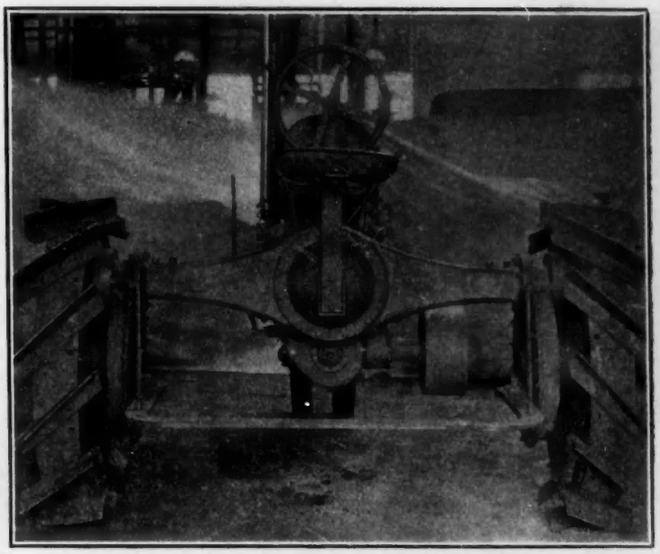
The afternoon session of the Tractor Meeting, at which Prof. O. W. Sjogren, of the University of Nebraska, presided, was devoted to an exposition and discussion of the development work that has been in progress for over a generation and resulted in the designing of farm tractors intended to replace to a great extent horses in agricultural and allied activities. O. B. Zimmerman, assistant to the manager of the engineering and experimental department of the International Harvester Co., exhibited many slides showing typical early and recent developments and also moving pictures of the various types of apparatus in operation.

The original steam-power equipment was intended to serve as portable belt-power units, these being used almost entirely to operate heavy threshing machines. Many men and horses and various supplies were needed in these operations. The extension of the use of tractors to plowing involved a number of new problems. About 20 years ago internal-combustion engines were utilized in farm tractors, the primary purposes of these being to plow and to supply belt power. Other operations, such as discing, harrowing and hauling loads on highways, were attempted but without much satisfaction owing to the relatively very great weight of the apparatus.

Ten years ago the efforts of engineers were devoted principally to reducing the weight of the tractors, which were in general suitable for belt and drawbar work. It was evident that improvements were demanded in plows, binders, harrows and mowers for use in connection with tractors. Implements of these kinds that had been designed to be drawn by horses were not entirely suitable for use with tractors, which had more power than horses, and also ran longer and at higher speeds. At this time the effort to effect one-man control of the tractor and its accompanying apparatus was largely successful.



View of the Farmall Showing Its Small Turning Radius
It Is Possible To Turn This Machine in a 15-Ft. Circle, Which Is an Advantage in Cultivating Row Crops. If the Operator So Desires, He Can Make the Turn around Either One of the Two Drive-Wheels as a Pivot, This Result Being Accomplished Automatically by a Brake That Operates in Connection with the Steering Wheel



Rear View of the Farmall
Note the 30-In. Clearance under the Rear Axle, Which Is Sufficient for Cultivating Corn, Cotton and Other Row Crops

Power Take-Off

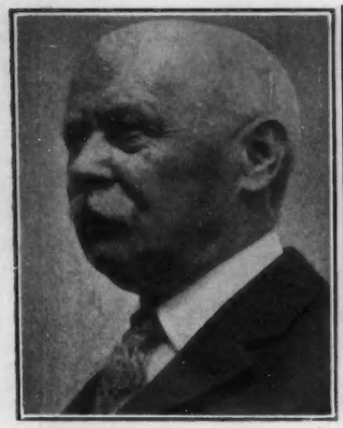
At this time the idea became prominent of transmitting power direct to the implement from the tractor powerplant, instead of through the driving wheels of the tractor. It is stated that this movement resulted in greater mechanical simplicity and reduced the total weight. Major Zimmerman said that the introduction of the power take-off was of fundamental and determining importance in the designing of general-purpose tractors.

According to statistics issued recently by the Department of Agriculture, in 1921 the acreage of row crops in this Country exceeded that of grain crops to the extent of 30,000,000 acres. This emphasizes the great need for the use of the tractor in cultivating work. Chairman Sjogren called special attention to this matter.

Major requirements in general-purpose tractor design are adequate ground clearance, proper wheel spacing and width of wheels and relatively short turning-radius.

In discussing general automotive engineering progress, Major Zimmerman called attention to the fact that the tractor industry has led in certain important phases of the whole development. He mentioned the use of kerosene as fuel; the starting of cold stiff engines, with the impulse-starter magneto; the use of oil-cooling systems, actuated principally by extremely low-temperature conditions in Northern fields; the use of the exhaust to induce draft in cooling systems; the installation of air-cleaners; and accessible unit-assembly construction.

The two accompanying views of the Farmall, the general-purpose farm tractor that has been developed by the International Harvester Co., gives a general idea of the construction of the machine. It is clear that machines of such type exemplify engineering achievement which is of the utmost value economically to agriculture and the world in general. The machine illustrated weighs about 3300 lb. and has a speed of about 3 m.p.h. It is said that with such apparatus the investment for equipment for the farm can be reduced greatly and the number of days of operation per year more than doubled. The general purpose has been to accomplish a maximum of operations with the minimum of apparatus in weight. The Farmall has a four-cylinder 3¾ x 5-in. engine that is rated at 20 hp.



J. F. Max Patitz
Second Vice-President Representing Tractor Engineering

O. W. Sjogren
Chairman of the Afternoon Session

In general it is stated that the cost of operation of this type of machine is at least half what it is with horses doing the same operations. The Farmall was shown in moving pictures doing the following kinds of work: cultivating; corn planting; plowing; mowing, binding and shocking and picking and threshing grain and "dusting" cotton, as well as sawing wood.

TRACTOR COSTS MUST BE DECREASED

Engineer Must Meet the Limited Buying Power of the Farmer in Future Designs

Whether the agricultural tractor industry can enjoy reasonable prosperity in the immediate future depends largely upon the engineer's ability to reduce the cost and increase the utility of the farm tractor itself. There is no other guarantee of a flourishing tractor industry until the slow but sure process of economics can work the farmer out of his present status of near-bankruptcy. These thoughts summarize the extremely interesting address of Cyrus McCormick, Jr., vice-president of the International Harvester Co., given before the National Tractor Luncheon of the Society in Chicago on April 24. While some of Mr. McCormick's comments bordered on pessimism, everyone present admitted that his frankness would lead to constructive thinking on the part of automotive engineers. Mr. McCormick's remarks are abstracted in the following paragraphs.

The commercial importance of engineering is to make good goods so that they are acceptable in every way to the buying public. I am very much of a pessimist for today, said Mr. McCormick; I am very much of a pessimist for tomorrow, but I am a perfectly marvelous optimist for day after tomorrow whenever that day comes. For the basic reason that people must eat, the day of prosperity for the farmer will come eventually. When that day comes, those who are interested in the production of things purchased by farmers may feel happier over the business situation.

No Group Can Prosper Unless All Prosper

Mr. McCormick cited the recent reduction in the Canadian tariff on agricultural implements to show how the farmers of that country were misled in believing that this decreased tariff, which assured them cheaper agricultural implements, would make them more prosperous. On the contrary, the workmen in the Canadian agricultural implement factories will be thrown out of work, deprived of their salaries and hence their purchasing power, and the farmer will suffer as a result. This illustration shows how all groups within a Nation are dependent for their prosperity upon the prosperous condition of all other groups.

We must recognize the fact that the farmer in the United States is not prosperous, that the law of supply and demand is working now as it always has worked, that 200,000 families have moved away from the farms in the year 1923 alone, that others are moving away now, that others will move away next year and that this migration will continue until the proper economic balance is reestablished. Until the time comes when there are so few farmers that there are not too many men to produce what the cities can consume, the farmer will not be prosperous. That is a very severe prospect, yet it is the only prospect that one can see if the situation is studied calmly, considerately and constructively. It is a necessary readjustment, a necessary leading back to the time when the farmer will have profits enough to buy agricultural implements and automobiles.

Labor Costs Must Be Reduced

Some day, when the necessary economic readjustment takes place, labor costs will come down and the tractor industry's problems will be solved. Something over 80 per cent of the costs of producing machines for the farmer in the International Harvester factories is represented by labor. Of course this does not mean that 80 per cent of the cost of an International tractor is direct labor. Rather, it represents the aggregate of the labor in all its component materials, the factory supplies and the like. Labor all along the line must be reduced to such a figure that the resulting cost of the agricultural implement is such that the farmer can afford to buy it and still have something left out of what he produces. Either that must happen or the farmer himself will have to receive so much money for his products that he will be raised to the present level of the urban workman.

What Can The Tractor Industry Do?

What are we going to do to meet a situation of this kind? Our products must be refined. For the present the commercial need of engineering is one not so much of blazing a new trail as it is of refining the work that we are now doing. Is there anything on the tractor that can be changed to make it operate just as efficiently as at present and yet make it possible to produce it more cheaply? If so, by all means make the change. Is there anything in the manufacturing processes in the shop that can be done more cheaply? If so, by all means take advantage of it. The agricultural implement business has tried to be efficient. Not a tractor is produced today that is not produced just as efficiently, unit for unit, as are the automobiles of the Country. There is nothing the automobile builder knows that the agricultural implement and tractor manufacturer does not also know and practise. It is incumbent upon the manufacturers of the Country to become just as efficient as they possibly can and yet no manufacturer can become efficient unless the engineer who precedes and guides him can show the way. That is the most significant point in agricultural engineering today.

The Tractor Engineer's Responsibility

It is up to the engineer in the pioneering of tractor designs to put them in such form that they can be acceptable to a farmer who is bankrupt. In other words, they must not only be good but they must be cheap. When you build for the farmer those things that he can afford to buy, he will again become your customer. The farmer is not in a position to pay any excess profit. Therefore, all we can do if we want the tractor business to prosper is to take all the excess profit out of it. Good goods must be made but the frills will have to be taken out of them and ultimately, if the tractor is simplified and reduced in cost, the real commercial object of engineering and manufacturing will have been accomplished and agricultural tractors and implements will be put back on a basis where the farmer can buy them.

TENTATIVE STANDARDIZATION WORK

Criticism of all tentative reports should be sent to the Standards Committee in care of the Society

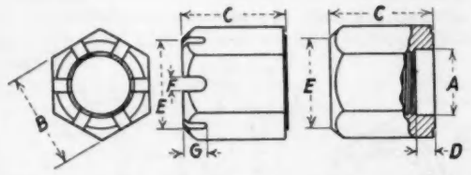
HIGH NUTS FACILITATE ASSEMBLING

Standard Proposed by Screw-Threads Division Developed To Increase Accessibility

The following definite recommendation for "high nuts" has been proposed by the S. A. E. Screw-Threads Division as a result of the use of nuts of this type by engine manufacturers interested in facilitating assembly and service.

E. H. EHRMAN

The present S. A. E. Standard plain and castle nuts are designed so that the height allows sufficient threads to develop a sheering strength equivalent to the tensile-strength of the bolt. It has been found, however, that when the standard nuts are used in more or less inaccessible places, it is extremely difficult to obtain sufficient purchase with a wrench to permit easy removal or to obtain the proper tightness.



Size (A)	B	C	D	E	F	G
1/4	7/16	3/8	1/16	25/64	5/64	1/8
5/16	1/2	29/64	5/64	29/64	5/64	9/64
3/8	9/16	17/32	3/32	33/64	1/8	5/32
7/16	5/8	39/64	7/64	37/64	1/8	11/64
1/2	3/4	11/16	1/8	11/16	1/8	3/16
9/16	7/8	49/64	9/64	51/64	5/32	13/64
5/8	15/16	27/32	5/32	55/64	5/32	7/32
3/4	1 1/16	1	3/16	63/64	5/32	1/4
7/8	1 1/4	1 5/32	7/32	1 5/32	5/32	9/32
1	1 7/16	1 5/16	1/4	1 21/64	5/32	5/16

All dimensions in inches.

As it was generally believed that an extra long nut was desirable as a standard product from both manufacturing and servicing points of view, information was obtained from engine and automobile builders as to the present practice of those that were using this type of nut. This information showed that over 68 companies were interested in such standardization and E. H. Ehrman, chairman of the Screw-Threads Division, made a careful study of their current practice.

The dimensions used in current practice were plotted and although practice was found to vary to a considerable extent, the following proportions were considered satisfactory for both design and production needs:

Diameter.—The same as for S. A. E. Standard castle and plain nuts

Width Across Flats.—The same as for S. A. E. castle nuts

Height of Nut.—Equal to the diameter plus the depth of the slot

Depth of Counterbore.—Equal to one-fourth of the diameter

Diameter across Top (E).—Such that thickness of wall is equal to ½ [¾ (B–A)]

Width of Slot.—The same as for S. A. E. castle nuts

Depth of Slot.—Equal to one-fourth the diameter plus 1/16 in.

Top Chamfer Angle.—Equal to 45 deg.

As the length of serviceable threads in the proposed series of slotted nuts is one diameter, and should not be less than this, the practice of counterboring instead of countersinking the face of the nut, as suggested by several manufacturers and users, should be specified only for plain nuts.

On account of the somewhat limited use of plain nuts and the slight differences between the dimensions of plain and slotted nuts, it was not found advisable to establish a separate series for plain nuts.

The standard proposed represents the preliminary report of the Division. Constructive criticism of the report will be appreciated by the members of the Division and should be sent to the Standards Department of the Society.

TRUCK BATTERY STANDARDS NEEDED

Battery Dealers Must Now Carry Unnecessary Stocks to Supply Replacements

In the last several years passenger-car starting-and-lighting batteries have gradually been reduced to seven standard sizes that are made interchangeably by the different battery manufacturers. This was accomplished through the active cooperation of the car and battery manufacturers aided by the Storage-Battery Division. The saving to the industry as a result of this simplification, or standardization, may be well appreciated if a thought be given to the conditions that would result in production, selling and especially in servicing if the industry should go back to conditions existing 10 years ago.

At the present time no S.A.E. Standard for motor-truck batteries for starting and lighting or for lighting only exists. W. E. Holland, chairman of the Storage-Battery Division, wishes to devote the entire work of the Division during the present year to the standardization of motor-truck batteries. In order that the Division might have complete information as to present practice, as standards must be based on present practice to be workable, each truck builder has been asked to submit complete data as to his present practice. These data will be tabulated and standard sizes based thereon, for it will probably be found that the industry has, to a large extent, standardized on certain sizes.

Standardization of motor-truck batteries is absolutely impossible, however, without the active cooperation of the truck builders. Unless they are in favor of restricting their purchases to the sizes standardized, battery manufacturers can be found who will make non-standard sizes. On the other hand, truck builders not entirely sold on the importance of

standardizing truck batteries can be influenced to abide by the standard sizes adopted, provided the battery manufacturers appreciate the importance of limiting production to only standard sizes and will explain matters clearly to such prospective purchasers.

The standardization of truck batteries thus becomes a matter for both manufacturers and users. The Society of Automotive Engineers, through the Storage-Battery Division of the Standards Committee, can only serve as a clearing-house for this work.

TOLERANCES RULES ESTABLISHED

Special Committee Proposes Five Rules for the Placing of Limits and Tolerances

Earle Buckingham, chairman of the Special Committee on Methods of Expressing Limits and Tolerances, has submitted the following five rules for dimensioning. These rules are based on the general information on dimensional tolerances that was approved at the 1924 Annual Meeting of the Standards Committee and is now published on p. M21 of the S.A.E. HANDBOOK.

The Committee proposes to review all existing S.A.E. Standards and Recommended Practices and to recommend revisions of those standards not dimensioned according to the rules established. This work will not be undertaken, however, until the Society has approved the rules proposed.

RULES FOR DIMENSIONING WITH TOLERANCES

Only one dimension in the same straight line can be controlled within fixed tolerances. That is the distance between the cutting surface of the tool and the locating or registering surface of the part being machined. Therefore, it is incorrect to locate any point or surface with tolerances from more than one point in the same straight line.

Every part of a mechanism must be located in each plane. Every operating part must be located with proper operating allowances. After such requirements of location are met, all other surfaces should have liberal clearances.

Dimensions should be given between those points or surfaces that it is essential to hold in a specific relation to each other. This applies particularly to those surfaces in each plane which control the location of other component parts. Many dimensions are relatively unimportant in this respect. It is good practice in such cases to establish a common locating-point in each plane and give, so far as possible, all such dimensions from these common locating-points. The locating points on the drawing, the locating or registering points used for machining the surfaces and the locating points for measuring should all be identical.

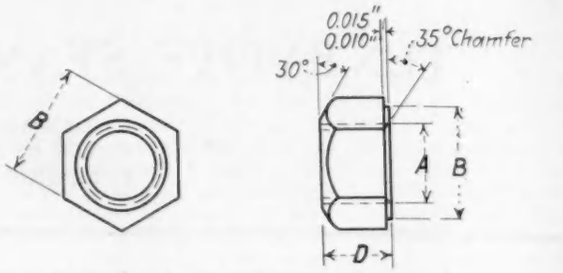
The initial dimensions placed on component drawings should be the exact dimensions that would be used if it were possible to work without tolerances. Tolerances should be given in that direction in which variations will cause the least harm or danger. When a variation in either direction is equally dangerous, the tolerances should be of equal amount in both directions, or bilateral.

The initial clearance, or allowance, between operating parts should be as small as the operation of the mechanism will permit. The maximum clearances should be as great as the functioning of the mechanism will permit.

AIRPLANE-BOLT STANDARDS PROPOSED

Subdivision Submits Changes in Present Standard for Hexagon-Head Bolts and Nuts

Edward Wallace, chairman of the Aeronautic Subdivision on Airplane Bolts and Nuts, has submitted a report covering extensive revisions of the present S.A.E. Recommended Practices for plain hexagon-head bolts and nuts and castle

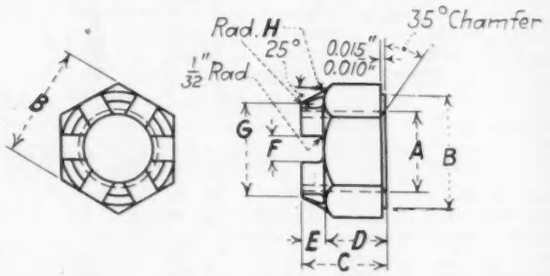


DIMENSIONS FOR AERONAUTIC PLAIN NUTS

Bolt Diameter, Min. (A)		Threads per Inch	Pitch Diameter of Nut		Rated Strength, Lb.	B	D
Nom.	Dec.		Max.	Min.			
6	0.1380	40	0.1235	0.1218	900	5/16	1/8
8	0.1640	32	0.1456	0.1437	1200	5/16	1/8
10	0.1900	32	0.1716	0.1697	1800	3/8	9/64
12	0.2160	28	0.1950	0.1928	2400	3/8	5/32
1/4	0.2500	28	0.2290	0.2268	3400	7/16	3/16
5/16	0.3125	24	0.2878	0.2854	5400	1/2	15/64
3/8	0.3750	24	0.3503	0.3479	8100	9/16	9/32
7/16	0.4375	20	0.4076	0.4050	11000	11/16	21/64
1/2	0.5000	20	0.4701	0.4675	15000	3/4	3/8
9/16	0.5625	18	0.5294	0.5264	19000	7/8	27/64
5/8	0.5250	18	0.5919	0.5889	24000	15/16	15/32
3/4	0.7500	16	0.7126	0.7094	35000	1 1/16	9/16
7/8	0.8750	14	0.8322	0.8286	4800 0	1 1/4	21/32
1	1.0000	14	0.9572	0.9536	65000	1 7/16	3/4

hexagon nuts, published in the S.A.E. HANDBOOK, pp. C59 and C60. The dimensions proposed by the Subdivision, which are given in the accompanying tables, will be acted upon at the next meeting of the Aeronautic Division and, if approved, submitted for final action at the Summer Meeting of the Standards Committee. The members of the Subdivision are Edward Wallace, of the Glenn L. Martin Co., George S. Case, of the Lamson & Sessions Co., W. R. Mitchell, of the National Acme Co., E. H. Ehrman, of the Standard Screw Co., and O. H. Hamm, of the Air Service.

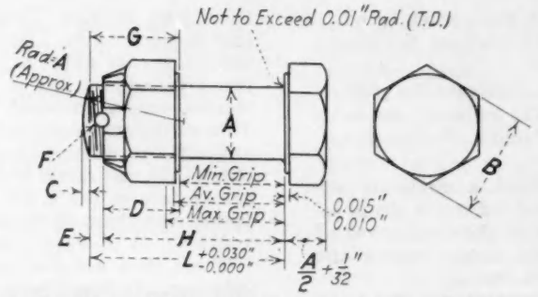
The bolt and nut dimensions proposed represent the following advantages over the present standards:



DIMENSIONS FOR AERONAUTIC CASTLE NUTS

Bolt Diameter, Min. (A)		Threads per Inch	Pitch Diameter of Nut		Rated Strength, Lb.	B	C	D	E	F	G	H
Nom.	Dec.		Max.	Min.								
6	0.1380	40	0.1235	0.1218	900	5/16	7/32	1/8	3/32	1/16	0.220	1/16
8	0.1640	32	0.1456	0.1437	1200	5/16	15/64	1/8	7/64	1/16	0.245	1/16
10	0.1900	32	0.1716	0.1697	1800	3/8	1/4	9/64	7/64	5/64	0.270	1/16
12	0.2160	28	0.1950	0.1928	2400	3/8	17/64	5/32	7/64	5/64	0.295	1/16
1/4	0.2500	28	0.2290	0.2268	3400	7/16	19/64	5/32	7/64	3/32	0.330	1/16
5/16	0.3125	24	0.2878	0.2854	5400	1/2	23/64	15/64	1/8	3/32	0.400	1/16
3/8	0.3750	24	0.3503	0.3479	8100	9/16	27/64	9/32	9/64	1/8	0.445	1/16
7/16	0.4375	20	0.4076	0.4050	11000	11/16	31/64	21/64	5/32	5/32	0.540	1/16
1/2	0.5000	20	0.4701	0.4675	15000	3/4	35/64	7/8	11/64	11/64	0.600	1/16
9/16	0.5625	18	0.5294	0.5264	19000	7/8	39/64	27/64	3/16	3/16	0.660	1/16
5/8	0.6250	18	0.5919	0.5889	24000	15/16	43/64	15/32	13/64	13/64	0.725	1/16
3/4	0.7500	16	0.7126	0.7094	35000	1 1/16	25/32	9/16	7/32	1/4	0.870	1/16
7/8	0.8750	14	0.8322	0.8286	48000	1 1/4	7/8	21/32	7/32	9/32	1.040	1/16
1	1.0000	14	0.9572	0.9536	65000	1 7/16	1	3/4	1/4	1/4	1.200	1/16

The greatest diameter of the chamfered part of the nut shall not exceed the major diameter.



DIMENSIONS FOR AERONAUTIC HEXAGON BOLTS

Nominal Size	Threads per Inch	Major Diameter (A)		Pitch Diameter		Rated Strength, Lb.	B	C		D	E	Drill Size (F)		Thread Length (G)	For L=1 In.			
																Grip		
		Max.	Min.	Max.	Min.			Max.	Min.			No.	Dec.		H	Max.	Nom.	Min.
6	40	0.1380	0.1350	0.1218	0.1201	900	5/16	0.020	0.015	7/32	1/16	55	0.052	9/32	15/16	0.781	0.750	0.718
8	32	0.1640	0.1610	0.1437	0.1418	1200	5/16	0.025	0.020	15/64	1/16	55	0.052	19/64	15/16	0.766	0.735	0.703
10	32	0.1900	0.1870	0.1697	0.1678	1800	3/8	0.030	0.020	1/4	1/16	50	0.070	5/16	15/16	0.750	0.720	0.687
12	28	0.2160	0.2120	0.1928	0.1906	2400	3/8	0.035	0.025	17/64	5/64	50	0.070	11/32	59/64	0.734	0.695	0.656
1/4	28	0.2500	0.2460	0.2268	0.2246	3400	7/16	0.040	0.030	19/64	5/64	48	0.076	3/8	59/64	0.703	0.665	0.625
5/16	24	0.3125	0.3085	0.2854	0.2830	5400	1/2	0.045	0.030	23/64	5/64	44	0.086	7/16	59/64	0.641	0.605	0.565
3/8	24	0.3750	0.3710	0.3479	0.3455	8100	9/16	0.055	0.040	27/64	5/32	38	0.101	17/32	29/32	0.579	0.530	0.485
7/16	20	0.4375	0.4335	0.4051	0.4024	11000	11/16	0.065	0.050	31/64	5/32	36	0.107	19/32	29/32	0.516	0.470	0.422
1/2	20	0.5000	0.4960	0.4675	0.4649	15000	3/4	0.075	0.060	35/64	3/32	36	0.107	21/32	29/32	0.453	0.405	0.359
9/16	18	0.5625	0.5575	0.5264	0.5234	19000	7/8	0.085	0.070	39/64	7/64	30	0.129	23/32	57/64	0.391	0.337	0.282
5/8	18	0.6250	0.6200	0.5889	0.5859	24000	15/16	0.090	0.075	43/64	7/64	30	0.129	25/32	57/64	0.329	0.275	0.220
3/4	16	0.7500	0.7450	0.7094	0.7062	35000	1 1/16	0.105	0.090	25/32	1/8	28	0.141	15/16	7/8	0.219	0.155	0.094
7/8	14	0.8750	0.8700	0.8286	0.8250	48000	1 1/4	0.120	0.105	7/8	1/8	24	0.152	1 1/32	7/8	0.125	0.062	0.000
1	14	1.0000	0.9950	0.9536	0.9500	65000	1 7/16	0.140	0.125	1	1/8	24	0.152	1 5/32	7/8	0.000	−0.062	−0.125

The cone shape distinguishes the aeronautic nut from the regular commercial nut.

The cone is a simple form to tool-up for and is lighter than the present form.

The wide slot allows free assembly of the cotter-pin, compensates for cotter-pin holes that are drilled a little off-center and permits the use of a stronger punch to shear the slot.

The end of the bolt is an arc with a definite radius.

The bolt length is measured to the first thread.

The cotter-pin hole is located two threads from the first thread.

The length of the thread is equal to the thickness of the nut plus the length of two threads.

Although the proposed dimensions represent considerable changes from the present standard dimensions, bolts and nuts made according to the proposed dimensions will be interchangeable with the present standard bolts and nuts. The Subdivision report also recommends cancelling the recommended practices for ball hexagon-head bolts and nuts, pp. C62 and C63, as these are now obsolete.

HEAD-LAMP STANDARDS REVISED

Recommendations To Meet Requirements of Motor-Vehicle Administrators Submitted

As a result of the conference between the Lighting Division members and the Eastern Conference of Motor Vehicle Administrators, which was reported on p. 385 of the April issue of THE JOURNAL, the Subdivisions of the Lighting Division have submitted several recommendations covering revisions of the present S. A. E. Standards and Recommended Practices for head-lamp equipment. These recommendations, which are given below, were submitted to the principal passenger-car builders for comment, with the request that those interested meet with the members of the Lighting Division at a meeting held on April 28.

At the conference between the Lighting Division members and the Lighting Committee of the Eastern Conference of Motor Vehicle Administrators it was intimated that if the car builders would not use such standards as were formulated to meet engineering and legal requirements, laws would be enacted in the several States that would require the inspection and approval of the entire car lighting equipment. Car lighting equipment designed to meet the recommendations proposed by the Subdivision will meet any legal requirements as they were formulated with the idea of presenting practice which, if followed, would assure head-lamps that would stand up in service and would not require continual readjustment such as is necessary at the present time as a result of the practice of car builders demanding the lowest-price lighting equipment obtainable without regard to whether the lamps will stand up in normal service.

PROPOSED REVISIONS

Door Construction.—Head-lamp doors shall be placed in the locking position by exerting a force parallel to the axis of the lamp. In attaching the door, the sealing material shall be held in compression by a convenient locking device that shall be mechanically operated from outside of the head-lamp. When the door is removed, the locking device shall remain attached to either the body, the door or the lock-ring.

Note:—While the above general type of door construction is recommended, what is commonly known as the bayonet type of locking device is recognized as making an easily accessible head-lamp and it is recommended that, as long as this type of head-lamp is used, one of the metals at each point of metal-to-metal contact where there is abrasive action shall be a non-ferrous metal alloy.

Focusing Mechanisms.—Where focusing adjustment mechanisms are used, the mechanism shall be constructed so as either to permit the focusing adjustment to be made outside of the head-lamp body, or the mechanism shall be mounted on the back of the reflector in such a manner as to be readily accessible without the removal of the lens.

Focusing mechanisms shall be constructed of non-rusting materials to permit freedom of adjustment at all times.

For alignment and stability purposes, the use of a reflector sleeve shall be employed having

(1) An inside diameter of from 0.692 in. minimum to 0.696 in. maximum

(2) Sufficient length to permit the socket to be keyed against rotation throughout the entire length of adjustment

(3) A friction device that will eliminate the play between the socket and the reflector sleeve throughout the entire length of the adjustment

Focusing mechanisms shall permit a minimum adjustment of the filament of from 5/32 in. in front of the focal point to 5/32 in. in back of the focal point of the reflector with an incandescent lamp having the standard light-center length of 1¼ in.

Means shall be provided to prevent the focusing screw from backing out.

Mountings.—Head-lamps shall be mounted so that their centers are not less than 32 in. nor more than 42 in. from the ground, but this distance should be as close to 36 in. as possible. The mounting shall provide for a change in the vertical and horizontal angle to permit the horizontal adjustment of the light beam to be brought parallel to the center-line of the car and the vertical adjustment to permit the light beam to be tilted 3 deg. below a plane parallel with the road surface.

Bolts used for mounting head-lamps shall be ½ in.-20.

Head-lamps shall be mounted on a vertical center-line with one bolt ½ in. in diameter and mounted on a bracket seat similar to the one shown on p. B1a of the S. A. E. HANDBOOK.

Electric Incandescent Lamps. — The light-center length for all electric incandescent lamps used in head-lamps for either electric or gasoline-propelled vehicles shall be 1¼ ± 3/64 in. as measured from the center of the filament field to the bulb side of the lock pins in the base.

The longitudinal axis of the lamp filament of the focal point shall not deviate more than 3/64 in. from the axis of the lamp base.

MANY "SHORT DIAMETERS" ELIMINATED

Action Taken at Washington Conference on Wrench-Head Bolts and Nuts Modified

The action taken on the standardization of wrench-head bolts and nuts at the conference held by the Division of Simplified Practice in the City of Washington on Feb. 19, which was reported on p. 339 of the March issue of THE JOURNAL, was modified at a meeting of Subcommittee No. 2 of the Sectional Committee on Bolt, Nut and Rivet Proportions held in New York City on April 18. At the Washington conference, the elimination of the 15/16 and 1-in. widths across flats, or short diameters as they are sometimes called, for the S. A. E. Standard bolt, nut and cap-screws were eliminated in favor of the 31/32-in. dimension. This action was reversed by the Subcommittee, all bolt heads and nuts so dimensioned being changed to 15/16 in. except the ¾-in. cap-screw which was changed to 1-in. The width across flats of the 1, 1⅛ and 1¼-in. bolts and nuts was also tentatively changed from 1¼, 1⅜ and 1½ in. to 1 5/16, 1½ and 1 11/16 in. respectively.

These sizes are not used to any extent in the automotive industry, finding their application in steam-engine practice. Although the increase in the head size will mean an increase in the cost, this is offset by the increase in strength and service.

The work of Subcommittee No. 2 may well be considered to be as, if not more, important than the work of any other committee. The report indicates that it will be feasible to eliminate at least one-half of the wrench openings now necessary for all bolts measuring less than 1 in. across flats. The resulting simplification in wrenches and bolt stocks will be reflected in large savings in dollars and cents and may be easily determined.

Consideration was also given to the elimination of all square-head cap-screws, but no final action will be taken until the feasibility of this action receives further study.

The tentative report of Subcommittee No. 2 proposes widths across flats for bolt heads, nuts and cap-screws as given in the accompanying table. If the Subcommittee report meets with the approval of the Society as sponsor, the dimensions marked with an asterisk would have to be adopted in place of the corresponding dimensions now specified in the present S. A. E. Standard for Bolts, Nuts and Screws, p. C2 of the S. A. E. HANDBOOK.

PRESENT S. A. E. STANDARD AND PROPOSED REVISIONS

Bolt Diameter	S.A.E. Bolt, Nut and Cap-Screw Heads	Proposed American Standard			
		Bolt Heads	Regular Nuts	Light Nuts	Cap-Screws
¼	7/16	3/8*	7/16	7/16	7/16
5/16	½	½	9/16	½	½
3/8	9/16	9/16	5/8	9/16	9/16
7/16	5/8	5/8	¾	5/8	5/8
½	¾	¾	13/16	¾	¾
9/16	⅞	⅞	⅞	⅞	13/16*
5/8	15/16	15/16	15/16	15/16	⅞*
¾	1 1/16	1 1/8*	1 1/8	....	1
⅞	1 ¼	1 5/16*	1 5/16*	....	1 1/8
1	1 7/16	1 ½*	1 ½*	....	....
1 1/8	1 5/8	1 11/16*	....	....	....
1 ¼	1 13/16	1 ⅞*	....	....	....
1 3/8	2	....	....	....	....
1 ½	2 3/16	2 ¼*	....	....	....

*Changes proposed in S. A. E. Standard.

DATA SHEETS INCORRECTLY PUNCHED

The S. A. E. HANDBOOK data sheets are cut with special dies and punched to close tolerances so that all new issues inserted in copies of the S. A. E. HANDBOOK will match the sheets retained. It has been found, however, that the first few hundred sets of the February, 1924, data sheets issued were incorrectly punched. The names of members receiving these sets are not known, but if they will send their sets to the Society, they will be replaced by sets that are punched correctly.

The check list that accompanied the February issue of data sheets indicated that data sheet B8c, dated August, 1922, had been superseded by data sheet B8c, dated March, 1923. Either sheet is correct, as the information thereon has not been revised.

AERONAUTIC SAFETY CODE TO BE PRINTED

Action was taken at the April 8 meeting of the Aeronautic Safety Code Sectional Committee, held at New York City, approving the printing of Parts 1, 2, 6, 7 and 10. The complete code comprises 10 parts as follows:

Part 1.—Airplane Structure
Part 2.—Powerplants
Part 3.—Equipment, Maintenance and Operation of Airplanes
Part 4.—Signals and Signaling Equipment
Part 5.—Airdromes and Airways
Part 6.—Traffic and Pilotage Rules
Part 7.—Qualification for Aviators
Part 8.—Balloons
Part 9.—Airships
Part 10.—Parachutes

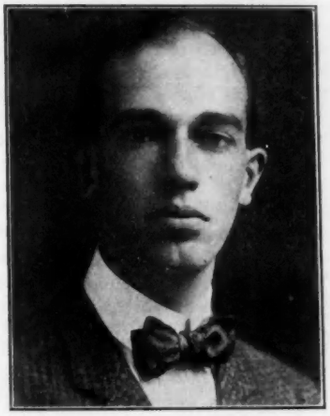
With the publication of the parts approved at this meeting, the complete code will be available in printed form and will be reprinted in a future issue of THE JOURNAL. Final committee approval will not be taken, however, until the tentative code has received wide publicity and an opportunity for constructive criticism has been afforded.

An introductory part, including a statement covering the

scope of the code and a glossary of the technical nomenclature used, is in course of preparation by a Coordinating Subcommittee consisting of H. M. Crane, chairman of the Sectional Committee, and the chairmen of the various working subcommittees.

HEAT-TREATMENT DEFINITIONS ANALYZED

Criticism of Proposals Based on a Comparison of Proposed Definitions



HUGH P. TIEMANN

In the April issue of THE JOURNAL, p. 384, appeared a short resumé of a preliminary report to the Iron and Steel Division on the coordinating of heat-treatment definitions, including certain proposals. Since that report was submitted, the American Society for Steel Treating has sent out for criticism definitions tentatively approved by its Recommended Practice Committee. In view of this situation, it will be of interest to go over these further definitions, which are presented below, as well as to consider the following comments, which are based on a comparison of the American Society for Steel Treating definitions with those previously submitted to the Iron and Steel Division by H. P. Tiemann, of the Carnegie Steel Co. Neither these comments nor the definitions previously submitted are intended to be the last word on the subject. It is hoped, however, that they will help to bring out constructive criticisms that will be useful in arriving at more generally acceptable definitions. As three societies, including the American Society for Testing Materials, are now engaged in formulating suitable definitions, it is desirable that steps be taken to effect the cooperation which is so necessary to harmonize present differences and produce results for the benefit of all concerned.

DEFINITIONS TENTATIVELY APPROVED BY AMERICAN SOCIETY FOR STEEL TREATING RECOMMENDED PRACTICE COMMITTEE

FOREWORD

During recent years, heat-treatments have become more and more complicated and as a result certain confusion has arisen in regard to the meaning of commonly used terms. For instance, in one locality or trade any operation of heating and cooling resulting in a softening of the material is being called annealing, whereas in other places to "anneal" means not primarily "to soften," but to heat to above the "critical temperature" and to cool very slowly. Similar confusion as to meaning and application exists in regard to other terms and as a result "annealing," "tempering," "normalizing" and the like are being used by different people to mean widely different things.

In any attempt to define accurately the terms commonly used in connection with heat-treatment, the first question to decide and the most important one is: Do the terms relate to the heat-treatment operation itself or to the results obtained by the treatment? In other words, is the term indicative of the structure or the condition obtained, or of the operation performed?

After careful consideration, it appears most logical and most in keeping with present-day usage to have the terms so defined that they shall mean definite operations and shall not be considered as referring to the structures or general conditions resulting, although, in a great majority of cases, the structures or conditions resulting may be very similar.

At first glance, it would appear entirely unnecessary to coin any new words. It seems, however, that one of the reasons for the confusion that exists is the lack of adequate terms with which to express the different operations and conditions encountered. In suggesting the use of the term "loneal," an attempt is made to relieve the term "anneal" of some of the misuse that it suffers and to eliminate the term "draw" that has wide application in regard to the mechanical operations performed on metals as distinct from thermal treatments.

In commercial practice, the terms here defined will vary slightly, depending upon the material under consideration. A "relatively slow rate of cooling" does not mean the same thing for an alloy-steel as for a plain carbon-steel, but the general meaning of the terms should remain the same regardless of the material being treated. This must be the case if the term relates to the actual operation and not to the structure or the condition resulting from the operation.

Heatings and coolings, during any part of which steel is worked mechanically, are excluded from the meanings of the terms here given.

By "heating" hereinbelow is meant a thorough and uniform penetration of the heat.

By "critical temperature" hereinbelow is meant that temperature which is customarily associated with the following phenomena:

(1) Hardening when quenched
(2) Loss of magnetism
(3) Absorption of heat
(4) Formation of solid solution
(5) Pronounced refinement of coarse grain upon cooling

HEAT-TREATMENT DEFINITIONS

Annealing.—Heating above the "critical temperature," followed by a relatively slow rate of cooling.

Loneal.—Heating below the "critical temperature," followed by any rate of cooling.

Normalizing.—Heating above the "critical temperature," followed by an intermediate rate of cooling.
Note.—In good practice the heating is considerably above the "critical temperature."

Spheroidizing.—A long-time heating at or about the "critical temperature," followed by slow cooling throughout the upper part of the cooling range.
Note.—For the purpose of spherodizing the cementite in high-carbon steels.

Hardening.—Heating above the "critical temperature," followed by a relatively rapid rate of cooling.

Tempering.—Reheating after hardening, to some temperature below the "critical temperature," followed by any rate of cooling.

Carburizing.—Adding carbon, with or without other hardening elements, such as nitrogen, to wrought iron or steel by heating the metal below its melting-point, in contact with carbonaceous material.

Case-Hardening.—Carburizing the surface portion of an object and subsequently hardening by suitable heat treatment.

Cyaniding.—A specific application of carburizing where the object, or a portion of it, is heated and brought into contact with cyanide salt.

In discussing, in the second and third paragraphs of the "foreword," whether the definitions should deal with the operation itself or with the results obtained, the statement is made that

> It appears most logical and most in keeping with present-day usage to have the terms so defined that they shall mean definite operations and shall not be considered as referring to the structures or general conditions resulting, . . .

It seems open to question whether this is "most logical" or "most in keeping with present-day usage." It is not obvious how a hard and fast rule can be laid down. The brief description constituting the definition may sometimes be better expressed in one way, sometimes in the other; again, a combination of method and purpose may be best adapted to make the meaning clear.

In the fourth paragraph of the foreword, the adoption of a new term, "loneal," and the elimination of an old term, "draw," is advocated. Any relief thus afforded the term "anneal" seems more fancied than real.

The "misuse" suffered by the term "anneal" is perhaps in its attempted restriction. This opinion is confirmed by the following quotation from a letter written by Dr. H. M. Howe, dated Nov. 29, 1913:

> "Annealing" is an exceedingly generic term, and must be held to include each and every softening operation. To attempt to restrict it to some special operation would be very strongly against my judgment.

The general tendency shown appears to be able to make the definitions more nearly a set of instructions or specifications. It would seem that such an object could be much more effectively attained by preparing complete specifications covering composition, treatment, tests, uses and the like and assigning to each a code word.

In the conclusion in the fifth paragraph of the foreword it is not clear why the meaning of the terms must remain the same regardless of the material being treated, because the term relates to the actual operation and not to the structure or the conditions resulting from the operation. It is just as easy to show that the same constancy of meaning can be secured by reference to the object sought. Doubtless when these definitions were drawn up the object of the operations was in each case considered, if not formally discussed, and because of its familiarity was considered superfluous. But how about the ordinary person without any knowledge of metallurgy in search of the definition of some unfamiliar term?

The exclusion of mechanical working, as referred to in the sixth paragraph of the foreword, as not permissible in conjunction with the heat-treating operation, appears to be untenable. Two cases will illustrate this:

> (1) To soften forgings, and thereby increase the ease of machining, they are frequently piled together immediately after they leave the hammer or the press. As they are admittedly softer when cold, as a result of this retarded cooling, than if exposed separately and freely to the air, it would certainly be splitting hairs to claim that they have not been annealed, at least to some extent
>
> (2) It is common practice in making helical railway-springs to coil them hot and quench them after they leave the coiling machines. There is no doubt that they are greatly hardened

If these two cases do not come under the head of heat-treatment, how are they to be classed? The fact that the treatment may not be of the best does not mean that heat-treatment is necessarily absent.

To the eighth paragraph of the foreword certain objections can be raised: that it is always a "temperature" and never a "range"; and that the first four conditions result on *heating;* that magnetism, for example, under most conditions is regained below such range or temperature; that the refinement of the coarse grain is produced by such heating. It may be preserved, but is not occasioned, by subsequent cooling.

Criticisms of Proposed Heat-Treatment Definitions

Annealing.—If the contention be granted that this is an operation for the purpose of softening, or relieving strains, or both, the following criticisms of this definition will be evident:

> It appears to be general, whereas it is restricted to steel or eutectoid or hypereutectoid compositions. The grain refinement is specified as a necessary condition. The relatively slow rate of cooling may not be required after the temperature is below the critical range.

Loneal.—This has been previously discussed.

Normalizing.—"*Intermediate* rate of cooling" is too indefinite in an isolated definition. The note is apparently not universally concurred in, as the British Engineering Standards Association in its definition says:

> . . . It is desirable that the temperature . . . shall not exceed the upper limit of the critical range by more than 50 deg. cent. (122 deg. fahr.).

Spheroidizing.—That the heating may be in the neighborhood of the critical range, is probably a better statement than restricting it to below the range, as certain authorities have pointed out that the action may so occur, although most effectively when slightly below. If the heating is slightly below the critical range, for example, why must the cooling be slow "throughout the upper part of the cooling range"? The note apparently restricts this treatment to high-carbon steels. Yet it is stated by Sauveur to be more effective in the case of low-carbon steels.

The definition previously submitted to the Iron and Steel Division has been slightly modified to read as follows:

> *Spheroidizing.*—Prolonged heating at a temperature in the neighborhood of, but preferably slightly below, the critical range to produce coagulation of the cementite into globules; usually followed by relatively slow cooling.

Hardening.—Is this definition aways true? This is presented as a general definition, and manganese steel, for instance, has not been excluded.

Tempering.—If the hardening has been effected otherwise than by quenching, heat-treatment, this definition is open to question. If the hardening were due to cold-working, this operation should more properly be styled annealing. The propriety of excluding mechanical working has already been discussed.

Carburizing.—The use of this term, without qualification, is questioned, as carburizing is also effected when the metal is molten, although, in the latter case, generally referred to as "recarburizing." Therefore, the term "carburizing by cementration" is suggested as being explicit. The British Engineering Standards Association uses the word "cementing." This last is not so common in this Country. In ordinary conversation or writing, "carburizing," without qualification, may be permissible, but hardly in a strict definition.

It seems preferable to follow the order "steel and wrought iron," instead of "wrought iron or steel," as in the latter case it is not clear that "wrought" does not also apply to "steel" in the sense of puddled steel that is practically no longer manufactured.

The reason for stating, "with or without other hardening elements such as nitrogen," is not appreciated. It is hard to understand how it would be carburizing without the addition of carbon and, furthermore, that the addition of other "hardening elements" need be more than merely incidental.

Case-Hardening.—The following rearrangement of the wording seems better to express the meaning intended:

> Carburizing, and subsequently hardening by suitable heat-treatment, the outer portion of an object.

The case is primarily what is to be hardened; the core is desired relatively soft in order to be tough.

Cyaniding.—It is suggested that the first part be made to read: "A method of surface hardening whereby the object . . ." This is in line with the discussion of "carburizing." The definition previously submtted to the Iron and Steel Division has been somewhat modified to read as follows:

> *Cyaniding.*—A method of surface hardening resulting when an object, or a portion of it, at the proper temperature, is in contact with a cyanide salt.
>
> *Note.*—This operation is usually followed by a suitable heat-treatment.

Hugh P. Tiemann

BRAKE-DRUM STANDARD UPHELD

Applies to Practice of Large Producers Rather Than That of Builders of Cars

The present S.A.E. Recommended Practice for Passenger-Car Brake-Drums, p. F1f of the S. A. E. HANDBOOK, was criticised by a chief engineer of a company producing quality cars to the effect that it was not in accordance with recognized engineering practice. Copies of this criticism were sent to the members of the Axle and Wheels Division and to members of the former Subdivision on Brake-Drums. Comments submitted by several members indicate that the present recommended practice represents the practice of over 90 per cent of current production and that if the practice proposed was specified, the cost of the brake-drums would be greatly increased.

The criticisms submitted in this connection are quoted herewith.

> Passing on recommendations such as these is a serious matter, as it implies that the Society is recommending these specifications. I am inclined to believe that no automotive engineer with any regard to quality would indorse the recommendation for brake-drums.
>
> Nothing is said about the material of which these brake-drums are to be made, but it is well known that the material under consideration is S.A.E. Steel 1010. This is a deep-drawing steel so soft and ductile that it can be used for cold-pressed stampings without fear of the stampings being elastic enough to spring out of shape when released from the dies. No poorer material could be specified for brake-drums, unless it were lead.
>
> We have heard no end of complaints in the press and elsewhere in regard to the poor brake mechanisms on American cars, and the brake-drum is undoubtedly the worst offender. The recommendations that we are asked to approve are based upon the brake-drum not being machined on the brake surfaces. This should not be sanctioned; all brake-drums should be machined on the brake surfaces.
>
> The stock that the brake-drums are made of should be thick enough to permit machining. No high-grade car should use brake-drums that are not machined on the braking surfaces. This is an absolute necessity in the case of four-wheel brakes, and the steel that the brake-drums are made of should have a carbon-content of not less than from 0.40 to 0.50 per cent. If made of high-carbon steel, the pressed-steel brake-drum manufacturers would not guarantee to meet an eccentricity of 1/64 in. for a 16-in. brake-drum.
>
> I certainly think the Society should hesitate before adopting any such specifications as those recommended for brake-drums. My objections can be summarized as follows:
>
> > The Society should not recommend brake-drum dimensions that are so small that they will not permit being machined on the brake surfaces.
> >
> > The Society should not recommend such an absurdly large tolerance as a 1/64-in. eccentricity on the finished brake surface of a 16-in. brake-drum.
> >
> > The Society should not recommend brake-drum dimensions that will make it impossible to use a steel of 0.50 per cent carbon or over.

The comments submitted in reference to these criticisms follow:

> Unquestionably the machined brake-drum has its advantages over the unmachined brake-drum; also the brake-drum with the higher carbon-content has its advantages over the brake-drum with a low carbon-content. The question of the high carbon-content is something new that came up within the last year, and the only manufacturers who are considering it are those building a high-grade car. Such orders as are placed are considered special.
>
> It was my opinion when we started out to standardize brake-drums that we did not intend to standardize drums for the high-grade car. The drums we did standardize without any question cover 90 per cent of the brake-drums used today.
>
> ---
>
> We fully understood that the dimensions given for brake-drum standards were for a finished drum, and that, therefore, engineers specifying machined surfaces for drums should allow another gage or two for finishing and establish and control their own eccentricity tolerances.
>
> No material is specified for these drums even though it is well known that the material now used is S.A.E. Steel 1010. We believe that the steel specification should be left open so that engineers may specify the carbon steel suitable for their requirements, but it must be understood that if the carbon-content is raised too high, the drum makers will have considerable trouble in drawing a drum even to the eccentricity tolerances now specified.
>
> One of our best-known customers recently increased the stock to ¼ in. on its light car and to 5/16 in. on its heavy car with the idea of providing stock for turning. The increase in gage also makes it possible to produce a more perfect drum through the press operations. This same customer is interested in high-carbon drums and no doubt will use high-carbon drums when we have demonstrated our ability to produce them economically.
>
> The high-carbon pressed-steel drum must be formed hot and will require one or two heat-treatments and a re-forming operation; also an extra pickling operation. The cost of the high-carbon drum is estimated to be about 50 per cent higher than that of the low-carbon drum.
>
> No doubt other manufacturers are contemplating changes in brake-drums and, due principally to the four-wheel brakes, an insistent demand has arisen for better drums, but up to the present time high-carbon pressed-steel drums have not passed the experimental stage.
>
> ---
>
> It is common practice to turn drums made from stock thicknesses specified in the proposed recommended practice after assembly. The objection to this practice is the fact that turning of the drum releases internal stresses and removes the tough outer skin that has been ironed by the drawing process. The gage thickness is not, however, reduced 1/32 in. by correcting for an eccentricity of 1/64 in. as inferred but rather only 1/64 in. or the amount of the eccentricity. The stock thicknesses recommended are inclined to be above rather than below the average practice.
>
> Unfortunately S.A.E. Recommended Practices must be based on present rather than future practice. It is possible that some other expression should be used as a caption for data of this nature to remove all objections.
>
> With few exceptions the tabulation represents the best, rather than the average, practice and should therefore tend to raise the standards of brake-drum practice, but not to the ideal proposed.

FRENCH ADOPT BATTERY STANDARDS

The Society has been advised by R. Gasquet, l'administrateur-déléqué of the Société Pour Le Développement Des Véhicules Electriques, that the French manufacturers have adopted the S. A. E. Standards for electric-vehicle charging plugs and storage-batteries. It is believed that this action will facilitate servicing in the future, especially where both French and American makes of electric vehicles are operated by one company.

AUTOMOTIVE RESEARCH

The Society's activities as well as research matters of general interest are presented in this section

FUEL RESEARCH OBJECTIVES STATED

Cooperative Work a Continuing Project to Maintain Engine-Fuel Balance

The cooperative fuel investigation has for some time been one of the major activities of the Society's Research Department. Its purpose and scope have been stated frequently but there is reason to believe that they are not, even now, clearly understood by all. This is not surprising, inasmuch as statements of the problem usually have been a part of the introduction to detailed reports, and readers are likely to pass over such preliminaries and to concentrate upon the actual results obtained and conclusions reached. In view of the apparent uncertainty as to the broad objectives of the research it seems in order to restate them briefly.

From the outset it has been the plan of the sponsors to establish the relation of fuel volatility to engine performance, not only for the year in which the investigation was undertaken but for subsequent years as well. In other words, the immediate program has been considered as but a part of the broader *continuing* project that has as its objective the securing and maintaining of a *correct balance* between the engine and the fuel. The obvious desirability of the continuing feature arises from the changes in fuels and equipment that occur from time to time.

The present investigation has been based upon a general recognition of the fact that certain automotive equipment is in actual service and that certain grades of automotive fuel are available. It has been the aim to determine the relative merits of these fuels for use in the existing equipment.

The results thus far obtained indicate that the increased dilution of crankcase oil is the outstanding consequence of lower fuel-volatility. As mentioned in the April issue of THE JOURNAL, a further investigation of the dilution problem among others is now in progress.

In keeping with the original project of maintaining a correct balance between the fuel and the engine, the next step will be to determine what changes, if any, in the previous conclusions are necessitated by recent progress in engine design; in other words, to keep the results uptodate.

NOTES ON CYLINDER HONING

Extensive Use of Process for Finishing Cylinder Walls Revealed by Survey

Honing as a process for finishing cylinder bores has come into extensive use among automobile and engine builders, and several of the leading companies that are at present finish-grinding their cylinders are known to be studying the possibilities of the newer process.

Some uncertainty as to the distinction between honing and lapping seems to exist among engineers, but in general the former term is correctly applied to the use of stones and the like as abrasives, while the latter is understood to involve the use of properly shaped tools or carriers charged with an abrasive such as emery. Precision of dimensions, closeness of fit and the polishing of surfaces may be considered the objectives of both processes.

A recent survey of cylinder-finishing methods made by the Society's Research Department included 24 of the well-known builders of automobiles and engines. Twelve of these use honing, nine are finish-grinding, while the remaining three are lapping.

At least one prominent company uses honing as a sizing and corrective operation to eliminate any of the high spots or other undesirable features that remain after reaming. The cylinders are first bored, then reamed to remove about 0.010 in. of metal and then honed to remove the last 0.001 in. Tolerances of 0.0005 and 0.0010 in. are set for out-of-roundness and taper respectively. In this case the bores are at present being honed separately in a vertical single-spindle machine; but a multiple-spindle machine better adapted to production work is being built. The abrasive stones are held rigidly in the rotating tool during the period of vertical travel through the cylinder.

At the beginning of the operation the lower end of the tool is inserted in the bore and the stones are brought into contact with the cylinder walls by an expansion device.

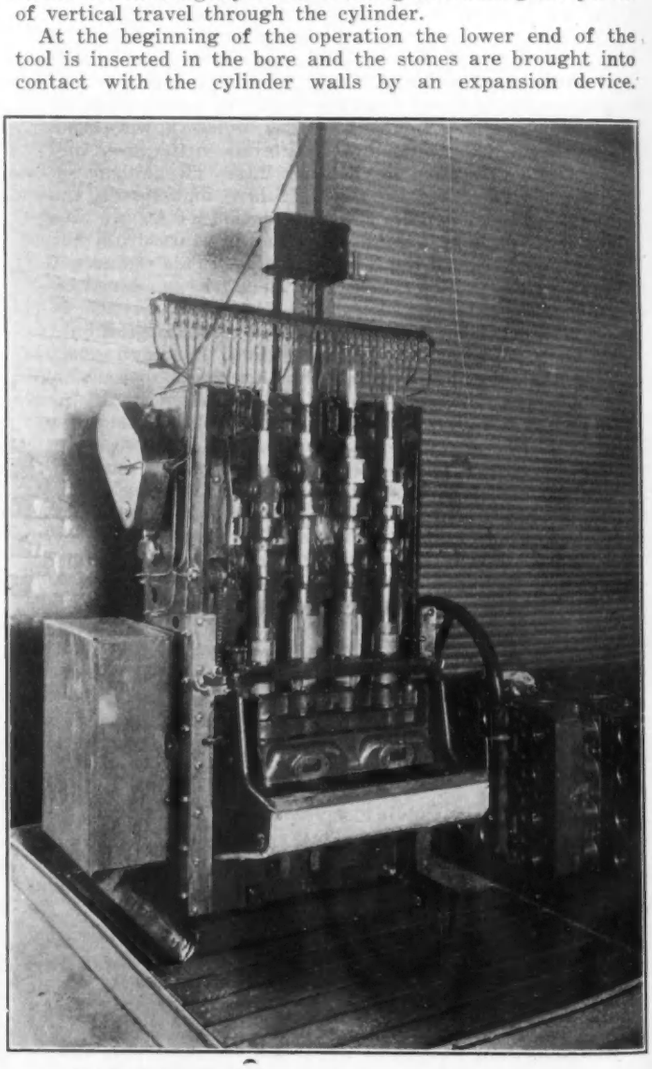


FIG. 1—HONING MACHINE USED AT THE LINCOLN PLANT
The Four Honing-Tools are Seen in Position Above the Cylinder Block

The tool is next fastened to the driving spindle of the machine through a coupling. Then it is fed through the cylinder at a reasonably slow rate while being rotated rapidly. Upon reaching the bottom of the bore the stones are again expanded into contact with the walls and the upward stroke is made. Kerosene is flooded upon the work as a lubricating and cooling medium.

In contrast with the above example, a majority of the shops depend entirely upon the reaming and grinding operations to give them sufficiently perfect cylindrical surfaces. They use the hone only as a means for removing the slight roughness or "fuzz" and to give a highly polished surface. In such cases the honing stones, usually three or four in number, are held against the work by springs inside the tool.

It is the practice in certain shops to give to the tool a rapid rotative motion and a slow travel along the cylinder axis; in others the tool is rotated very slowly and moved rapidly along the axis; while in others it is not rotated within the bore but only at the completion of each stroke, and then by small but unequal steps of a few degrees each.

The practice at the Lincoln plant may be taken as an example of the method last mentioned. Here it is believed that the pistons of an automobile engine should not be required to finish and polish the cylinder walls when the honing method of finishing makes possible the production of a better running engine and the elimination of the "breaking-in" process often specified for new cars. Fig. 1 shows the honing machine and the tools that finish four cylinders at a time.

Before being honed the cylinders are bored in 3 steps, then ground in 8 or 10 steps with cooling and seasoning periods of 4 or 5 hr. between grindings. To obtain the final finish the cylinder block is set in the honing machine and the tools take up a reciprocating motion without rotation within the bores. The hones are rotated or indexed, however, by unequal steps at the end of each stroke. The carborundum stones are held against the work by springs within the tool. This honing operation produces a mirror-like finish but is not used as a sizing or corrective measure; an extremely small amount of metal is removed from the walls. Kerosene is used as a lubricating and cooling medium.

TECHNICAL QUESTIONS ANSWERED

Department Serves Members by Supplying Information on Various Subjects

A very interesting activity of the Research Department is the information service. Questions are received through letters and by telephone, and personal consultation forms an appreciable part of the work. The time needed to answer an inquiry varies all the way from the few minutes necessary to look up a definite reference in an index file to several hours of real investigation in the library and elsewhere, and it often involves writing to experienced men in the industry concerning their practice with regard to a given problem.

Making Babbitt Adhere to Cast Iron

Recently the Department was asked to furnish information regarding the method of making babbitt adhere to gray iron; the inquirer was using a babbitt bearing with a cast-iron back and was having trouble because the babbitt came loose from the bearing.

In this connection, the following statement, which was received from an authority in this field, was sent to the inquirer and is passed on as of possible interest to readers.

> To make babbitt adhere to cast iron, it is first necessary to cover the surface to be babbitted with a coating of tin. This operation requires considerable care, several methods being employed for this purpose.
>
> One method is to electroplate the cast-iron surface with copper and then proceed to tin this in the same way as with an ordinary bronze-backed bearing. Another method is to hold the surface to be tinned against a revolving brush made of small brass wires. This wears off the ends of the brass wires and the brass particles seem to embed themselves in the pores of the cast iron. The result is much the same as electroplating, and the tinning is done in the same way.

Formulas for Horsepower Rating

Several inquiries recently received have related to the Dendy Marshall formula for horsepower rating. It is thought that a comparison of this British formula with that of the National Automobile Chamber of Commerce may prove interesting.

The Dendy Marshall formula is

$$Hp = D^2SN \div 12$$

where

D is the cylinder bore in inches
N is the number of cylinders
S is the stroke in inches

and where a speed of 1000 r.p.m. is assumed.

The N. A. C. C. horsepower rating, formerly known as the A. L. A. M. rating and sometimes referred to erroneously as the S.A.E. formula, is

$$Hp = D^2N \div 2.5$$

where

D is the cylinder bore in inches
N is the number of cylinders
2.5 is a constant representing a conservative rating for a four-cycle engine at 1000 ft. per min. piston speed. As a matter of fact, the 1000 ft. per min. stipulation does not apply very well to present-day conditions

For a comparative application of the two formulas, a six-cylinder engine will be considered, having a bore and a stroke of 3⅜ in. and 4¾ in. respectively. According to the Dendy Marshall formula, a horsepower of 27.05 would be the result of the calculation, whereas the N. A. C. C. formula would give 27.34.

POLITICAL ECONOMY

POLITICAL economy, properly understood and properly applied, is not a dreary science, but one of the most fascinating and mentally stimulating of all forms of human knowledge. Above all, it is one that gives real hope for making a better business of human life in the future than was ever known in the past; far better than anything the communist theorizers can offer. Let their theories be examined, not with sentimental indulgence but in the scientific spirit, and they fade away like the dreams they are. Even business men and traders, who ought to know better, ignore the science on which their livelihood is wholly founded.—J. St. L. Strachey.

Observations of a Superintendent of Motor-Truck Fleet-Operation

By J. F. WINCHESTER[1]

METROPOLITAN SECTION PAPER *Illustrated with* PHOTOGRAPHS AND CHARTS

SOLICITATION of sales and the delivery of the product to the customer constitute the most important operative features of the motor-truck fleet supervised by the author. Endeavor is made to install the vehicles in the various fields along standardized lines. The volume and the extent of the business and the topographical conditions of each locality determine the size and the mechanical equipment of the vehicle that is employed, and it is installed only after a study of all the conditions pertaining to its operation.

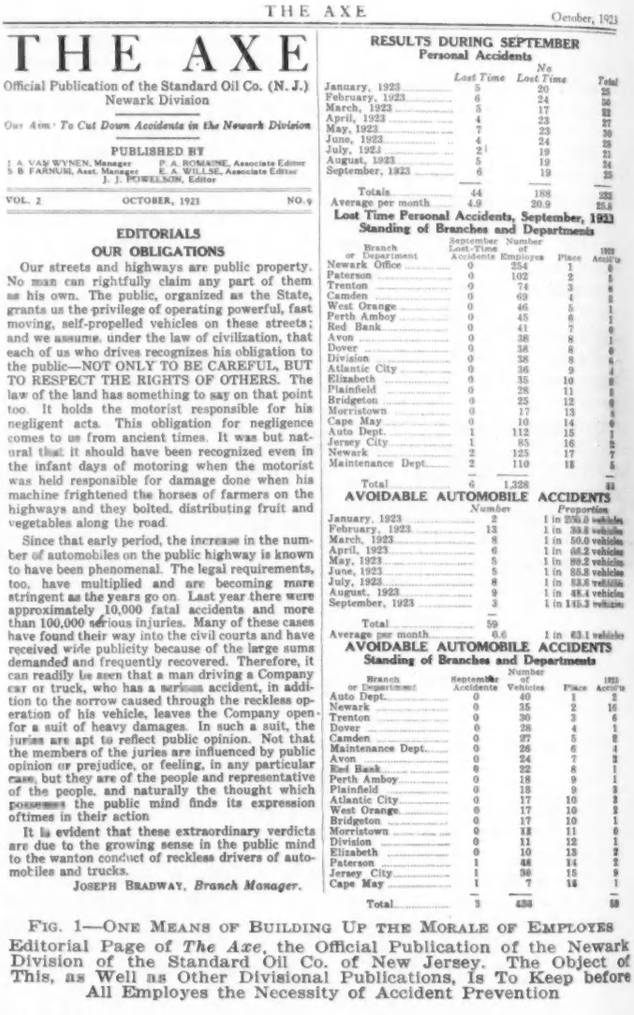
Adequate training of vehicle operators, not only along mechanical lines but also as direct sales representatives of the company, is made a feature; and so is accident prevention. These interests are promoted in various standard ways and are furthered by the publication of "house organs." After a vehicle is installed the slogan adopted is: Keep It Moving With a Pay Load.

Methods of mechanical upkeep are outlined, special tools and fixtures used are illustrated and valuable details of maintenance practice are stated. Engineering factors that affect fleet operation are discussed, as well as details relating to tire selection. A magazine system of chassis lubrication is advocated. Brakes, wheels and accessories are treated from the standpoint of design, simplicity and accessibility being the keynote. Operating costs, records and record forms are considered in general and, since adequate records are a necessity if fleet operation is to be successful, some specific recommendations are made concerning them.

MANUFACTURING and selling of petroleum products constitute the business of the company with which I am associated. In its conduct, transportation plays an important part. From observation, it would appear that if all the types of transportation employed be considered, namely: pipe-line, marine, railroad, horsedrawn-vehicle and motor-vehicle, greater opportunity probably is afforded for the ready adoption of the most economical method on a large scale than is true of any other industry. For economical results, it is necessary that the motor vehicle be employed for various purposes. The greatest number of such vehicles are used for the solicitation of sales and for the delivery of the product to the customer. No sharp distinction can be made between these two classifications, because the motor-truck operator is also a solicitor who is trained and encouraged in this line. In fact, some of our most responsible positions are filled by men whose early efforts as tank-wagon salesmen placed them in line for promotion. In our business the motor truck is used for delivery and for sales promotion, and I believe this is true in other lines of business.

GENERAL OPERATIONS

We endeavor to install vehicles in the various fields along standardized lines. The volume and the extent of the business and the topographical conditions of each locality determine the size and the mechanical equipment of the vehicle that is employed. To facilitate the mechanical service-problem and the instruction of operators, it is necessary to employ in a given class, so far as practicable, as few individual makes of vehicle as possible and still permit comparative observation. Therefore, a vehicle is installed only after a study of all the conditions pertaining to its operation, and a statement is prepared showing its probable cost of operation from a comparative standpoint. Its mechanical specifications are prepared with the idea of holding its component parts, such as gear ratios, cabs, tires, lighting equipment, speedometer and magneto, within certain standards. Generally, we have found that the builders and their engineers are willing to assist in the maintenance of definite standards



THE AXE October, 1923

THE AXE

Official Publication of the Standard Oil Co. (N. J.) Newark Division

Our Aim: To Cut Down Accidents in the Newark Division

PUBLISHED BY

J. A. VAN WYNEN, Manager P. A. ROSAINE, Associate Editor
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J. J. POWELSON, Editor

VOL. 2 OCTOBER, 1923 NO. 9

EDITORIALS

OUR OBLIGATIONS

Our streets and highways are public property. No man can rightfully claim any part of them as his own. The public, organized as the State, grants us the privilege of operating powerful, fast moving, self-propelled vehicles on these streets; and we assume, under the law of civilization, that each of us who drives recognizes his obligation to the public—NOT ONLY TO BE CAREFUL, BUT TO RESPECT THE RIGHTS OF OTHERS. The law of the land has something to say on that point too. It holds the motorist responsible for his negligent acts. This obligation for negligence comes to us from ancient times. It was but natural that it should have been recognized even in the infant days of motoring when the motorist was held responsible for damage done when his machine frightened the horses of farmers on the highways and they bolted, distributing fruit and vegetables along the road.

Since that early period, the increase in the number of automobiles on the public highway is known to have been phenomenal. The legal requirements, too, have multiplied and are becoming more stringent as the years go on. Last year there were approximately 10,000 fatal accidents and more than 100,000 serious injuries. Many of these cases have found their way into the civil courts and have received wide publicity because of the large sums demanded and frequently recovered. Therefore, it can readily be seen that a man driving a Company car or truck, who has a serious accident, in addition to the sorrow caused through the reckless operation of his vehicle, leaves the Company open for a suit of heavy damages. In such a suit, the juries are apt to reflect public opinion. Not that the members of the juries are influenced by public opinion or prejudice, or feeling, in any particular case, but they are of the people and representative of the people, and naturally the thought which possesses the public mind finds its expression oftimes in their action.

It is evident that these extraordinary verdicts are due to the growing sense in the public mind to the wanton conduct of reckless drivers of automobiles and trucks.

JOSEPH BRADWAY, *Branch Manager.*

RESULTS DURING SEPTEMBER
Personal Accidents

	Lost Time	No Lost Time	Total
January, 1923	5	20	25
February, 1923	6	24	30
March, 1923	5	17	22
April, 1923	4	23	27
May, 1923	7	23	30
June, 1923	4	24	28
July, 1923	2	19	21
August, 1923	5	19	24
September, 1923	6	19	25
Totals	44	188	232
Average per month	4.9	20.9	25.8

Lost Time Personal Accidents, September, 1923
Standing of Branches and Departments

Branch or Department	September Lost-Time Accidents	Number of Employes	Place	1923 Accidents
Newark Office	0	254	1	6
Paterson	0	102	2	5
Trenton	0	74	3	6
Camden	0	69	4	8
West Orange	0	46	5	1
Perth Amboy	0	45	6	1
Red Bank	0	41	7	0
Avon	0	38	8	1
Dover	0	38	8	0
Division	0	38	8	6
Atlantic City	0	36	9	4
Elizabeth	0	35	10	0
Plainfield	0	28	11	1
Bridgeton	0	25	12	0
Morristown	0	17	13	4
Cape May	0	10	14	0
Auto Dept.	1	112	15	1
Jersey City	1	85	16	2
Newark	2	125	17	7
Maintenance Dept.	2	110	18	5
Total	6	1,328		81

AVOIDABLE AUTOMOBILE ACCIDENTS

	September Number	Proportion	1923 Accidents
January, 1923	2	1 in 256.0 vehicles	
February, 1923	13	1 in 33.6 vehicles	
March, 1923	8	1 in 50.0 vehicles	
April, 1923	6	1 in 66.2 vehicles	
May, 1923	5	1 in 89.2 vehicles	
June, 1923	5	1 in 85.3 vehicles	
July, 1923	8	1 in 53.8 vehicles	
August, 1923	9	1 in 48.4 vehicles	
September, 1923	3	1 in 145.3 vehicles	
Total	59		
Average per month	6.6	1 in 63.1 vehicles	

AVOIDABLE AUTOMOBILE ACCIDENTS
Standing of Branches and Departments

Branch or Department	September Accidents	Number of Vehicles	Place	1923 Accidents
Auto Dept.	0	40	1	2
Newark	0	35	2	16
Trenton	0	30	3	6
Dover	0	28	4	1
Camden	0	27	5	8
Maintenance Dept.	0	26	6	4
Avon	0	24	7	2
Red Bank	0	22	8	1
Perth Amboy	0	18	9	1
Plainfield	0	18	9	3
Atlantic City	0	17	10	3
West Orange	0	17	10	2
Bridgeton	0	17	10	1
Morristown	0	13	11	0
Division	0	11	12	1
Elizabeth	0	10	13	2
Paterson	1	48	14	2
Jersey City	1	30	15	9
Cape May	1	7	16	1
Total	3	430		59

FIG. 1—ONE MEANS OF BUILDING UP THE MORALE OF EMPLOYES Editorial Page of *The Axe*, the Official Publication of the Newark Division of the Standard Oil Co. of New Jersey. The Object of This, as Well as Other Divisional Publications, Is To Keep before All Employes the Necessity of Accident Prevention

[1] M.S.A.E.—Supervisor of motor equipment, Standard Oil Co. of New Jersey, Baltimore.

of this nature. After it is installed, the vehicle is operated to its maximum efficiency through the cooperation of all concerned, so that the maximum output can be obtained and the minimum repairs made with the least possible waste of time.

Training of Operators

It has been stated that successful truck operation depends upon the operator. This is true in some degree but the extent to which it is true depends upon the size of the operation or the fleet being operated, and the type of vehicle employed. A good organization, carefully worked out so that the operator's work is planned for him and his whole energy can be devoted to delivery and minor repairs that may need to be made in an emergency, will produce far better results than those obtained when the operator is called upon to perform duties or functions that are beyond his business training or mechanical experience.

Fig. 2—The No-Accident Emblem Used in the State of New Jersey

Each New Driver Receives One of These Emblems, Which Has His Name Painted on It. This Emblem Is Attached to the Vehicle and Remains in the Possession of the Operator until He Meets with an Accident

We recognize the merits of training the operator along sales and mechanical lines, for, in many localities, he is the company's direct representative. This training is done through general welfare work. It includes (*a*) an opportunity for all in the company's service 1 year or more to become stockholders, (*b*) an industrial-representation plan that permits free discussion of the various problems involved in the operation of motor vehicles or any other problems affecting the company's welfare and

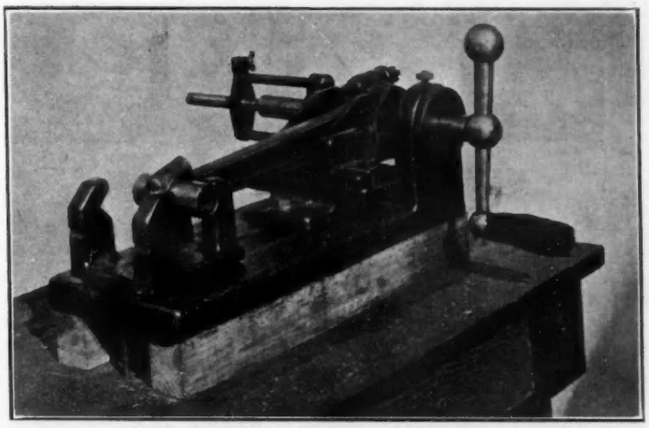

Fig. 4—Connecting-Rod Bearing Single-Point Boring Tool

This Tool Takes the Place of a Reamer and Produces a More Accurate Bearing with No Chatter-Marks. Adjustment to Any Diameter Can Be Made, Thus Giving Practically a Perfect Bearing That Requires No Scraping

(*c*) general educational work along sales, operating and safety lines, conducted by lectures and through educational matter disseminated by the "house organs" that carry our message to the various employes regularly.

Safety

One of the problems presented to the operator of motor vehicles is that of accident prevention. It is overlooked by many and held in derision by others. This constant menace often is ignored until it is forcefully brought to attention by having a loved one become the victim of the negligence of others. Fleet operators should recognize this problem because accident reduction means reduced insurance rates, a smaller percentage of lost time and a general saving in repair costs and depreciation. A study of accidents in one section of our fleet is presented in Table 1 and shows the average repair cost per vehicle per accident by class.

TABLE 1—AVERAGE REPAIR-COST PER VEHICLE PER ACCIDENT

Kind of Vehicle	Number of Accidents	Repair Cost Total	Repair Cost Average for Each Accident
Passenger Car	27	$1,157.12	$42.86
Service Car	11	302.33	27.48
Motor Trucks			
2½ Ton	44	1,213.79	27.59
3½ Ton	12	1,357.55[a]	113.13
5½ Ton	9	338.58	37.62
	103	$4,369.37	

[a] Includes one severe accident.

Fig. 3—When Motor-Truck Equipment Is Operated over Roads of This Character the Period between Overhauls Is Shortened

The End Views Show the Road Conditions Encountered by a Truck Operating over a Route in the Carolinas. The Central View Illustrates the Roads in the City of Florence, S. C., in February, 1921

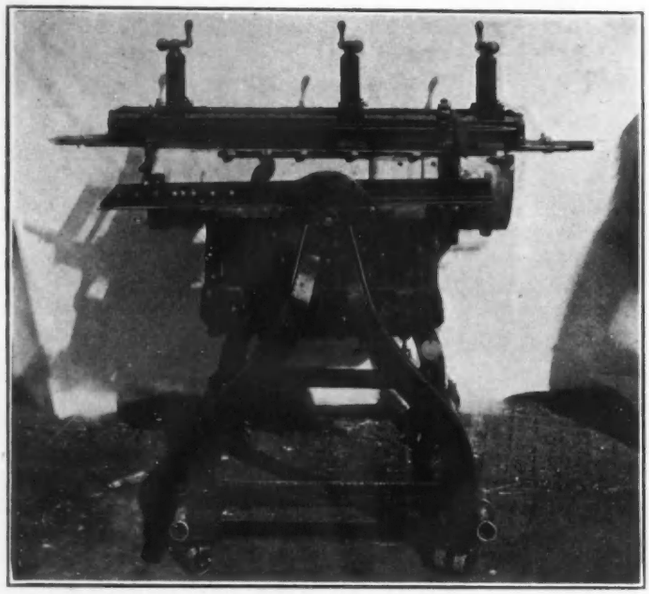

FIG. 5—SIDE VIEW OF THE ENGINE-STAND AND MAIN-BEARING TOOL

The Stand Can Be Adjusted for Different Operations. The Main Bearing Tool Is of the Single-Point Type and Is Capable of Producing Finely Finished Accurate Bearings of Various Sizes Which Require Practically No Scraping or Fitting of the Crankshaft

In addition to the direct cost shown in Table 1, loss of time and probable lawsuits must be figured as an overhead charge, the percentage depending on the individual operator.

We keep before all employes the necessity of accident prevention through division publications that are filled with live topics. One of these has a particularly appropriate title, *The Axe;* the editorial page of a recent issue is reproduced in Fig. 1. This, together with another divisional paper along similar lines, has a circulation of 4000 copies. Some subjects covered recently are: New Year Resolution of a Motor-Vehicle Operator; Give Service with Safety; What Has Lubrication To Do with Accident Prevention; How to Avoid Skidding; The Horn; and The Cost of Accidents. In addition to our own publications, we have used valuable matter published by various firms and promoters of safety campaigns, which matter usually can be obtained by the smaller operators on request.

Accident prevention has a definite place in motor-vehicle operation. It is a subject that covers many phases of engineering. In New Jersey we furnish each new driver of our motor-vehicle equipment with a "No Accident" emblem, as illustrated in Fig. 2; it is attached to the vehicle and has the driver's name painted on it. This remains in the possession of the operator until such time as he meets with an accident. Certain definite rules are laid down and, before this emblem is taken away from an operator for a period of time, a committee of three passes upon all phases of the situation in connection with the accident. We have found that this emblem is valued and that the operator takes pride in it, so that he makes every effort to keep his accident record unblemished.

FIG. 7—SPECIAL FIXTURE FOR FITTING BEARING SHELLS

The Construction of This Fixture Enables Bearing Shells To Be Dressed Off to the Correct Height and Placed in the Case without Further Fitting. Hardened Rollers That Prevent Damage to the Files, Which Are Spaced To Give the Proper Height on the Shell when Finished, Are a Special Feature

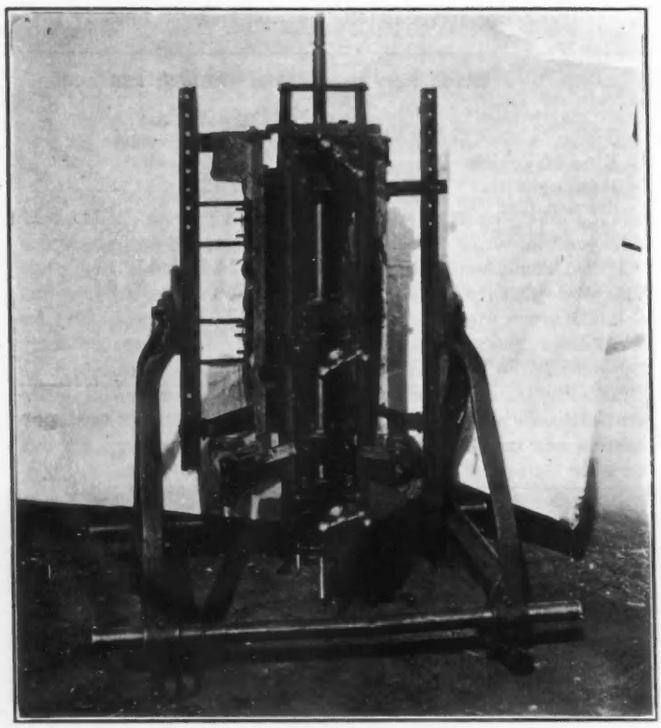

FIG. 6—PLAN VIEW OF THE ENGINE-STAND AND MAIN-BEARING TOOL SHOWN IN FIG. 5

The Construction of the Stand and the Tool Are Brought Out in More Detail in This Illustration

MECHANICAL UPKEEP

After a motor vehicle is installed, a good slogan to keep in mind is: Keep It Moving with a Pay Load. Assuming that this is being done, the next considerations are its mechanical upkeep and probable life. My opinion is that a suitable running repair system must be maintained to get the most out of a vehicle and to give the best results without an interrupted service. Any vehicle is subject to a general line of ills, such as electrical troubles, carbureter maladjustments and lubrication difficulties. With each type or make of truck certain weak points are soon noted that necessitate periodical attention. Systematic care and prompt attention to them will save expense. This is done in our case by first-class repairmen who have assigned to them a certain number of vehicles to keep in shape. They first inspect and then make repairs on the spot. They do all classes of work up to adjusting connecting-rods or replacing them, in the field, and are responsible for the mechanical upkeep of the vehicle after it reaches the field until it comes into the shop again.

How long does a motor vehicle stay in the field? As long as its appearance and mechanical condition will

permit. No given time or mileage is assigned to a vehicle. To do so would not be practicable; nor is it practicable to compare the operation of one vehicle with that of another unless conditions, such as roads, gear ratios and loads, are nearly alike. Trucks operating in Northern cities should have a longer life than those that operate in Southern cities. Road conditions are in their favor. How many have realized the difference in conditions? The photographs reproduced in Fig. 3 will give a fair idea of the type of road conditions our equipment encounters that tend toward short periods between overhauls.

Vehicle-life comparisons depend upon varying factors that in many instances are comparable in like fields of endeavor. By like fields of endeavor is meant operators in the contracting, bus, express or furniture business, and the like, in given localities, where road and weather conditions are approximately the same. These two factors are important ones: First, in the selection of gear ratios; second, in the wear-and-tear that is imposed upon the mechanism by the elements. When the time is reached that the vehicle has to come into the shop, it is necessary that it be handled with dispatch and by an

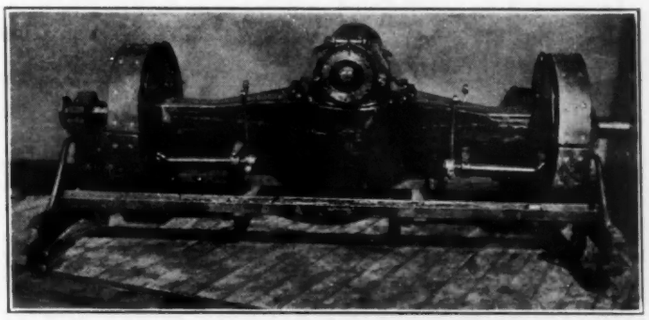

FIG. 9—CHASSIS AXLE ASSEMBLY STAND
Making This Stand Low-Hanging Enables Axles To Be Removed from or Placed under a Chassis or Moved from One Part of the Shop to Another Conveniently

the shop and enable prompt emergency repairs to be made. Specialists are employed, so far as is practicable but, where necessary and proper aptitude is shown, these are developed into general all-round repairmen.

Shop operations should be watched carefully. Care should be exercised in the analysis of the labor cost that

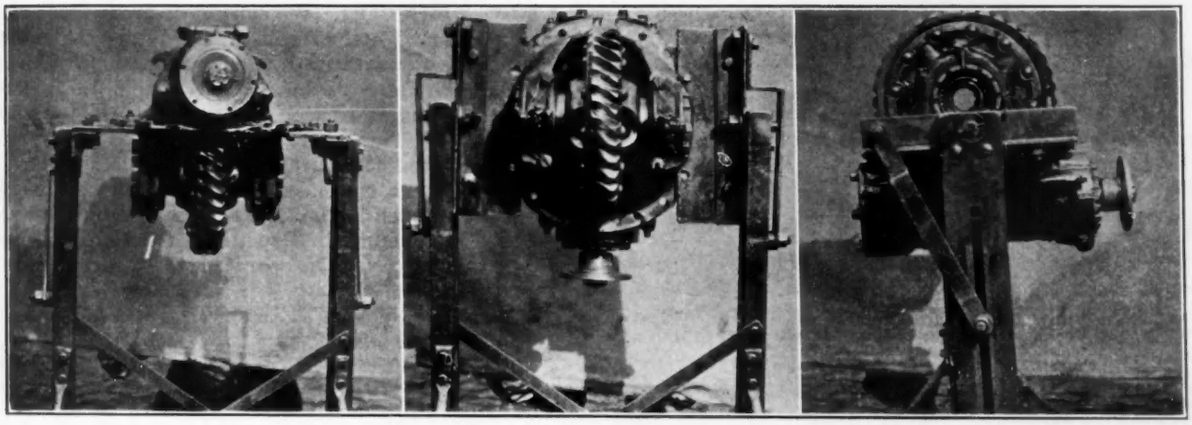

FIG. 10—THREE VIEWS OF THE WORM-UNIT UNIVERSAL REPAIR-STAND
The Construction Is Such That Worm-Differential Assemblies Can Be Overhauled Readily Since the Unit Can Be Worked on from Different Positions

organization that understands thoroughly the product it is repairing. Indifferent overhauls result in much lost time and a duplication of effort. We use the so-called unit method of repairs. Thus we facilitate the work in

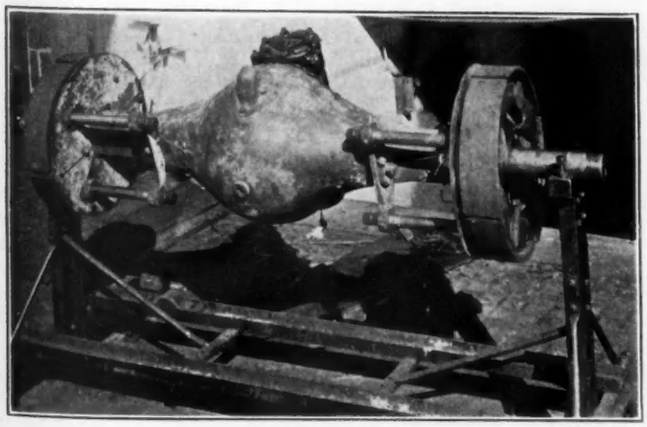

FIG. 8—AXLE ASSEMBLY STAND
This Stand Is Especially Useful in Holding Worm-Drive Axles So That They Can Be Worked on Conveniently

enters into the repair of a given unit, so that the time taken will be within reason. Modern tools and production methods should be employed, so far as possible, and the selection of tools should be made with care. Many devices have a general sales appeal and they are apt to run into investments that will prove unprofitable. To promote the economical use of a given type of vehicle a great opportunity still exists for many distributors to get before the users of their product the time-saving assembly or overhaul devices that are aptly applied in their service-stations or assembly plants. Some of the special tools we use are illustrated in Figs. 4 to 12.

Not only do we try to place the most up-to-date repair tools in the shop, but we coordinate the various practical points in design with these activities in such a way that the shop force will have before it the various kinds of mechanical information that are necessary for good workmanship. For instance, engines will not operate properly if the spring pressures are not up to a maximum, so we have the pressures tabulated as shown underneath Fig. 12. We tabulate pistons, piston-rings, valve guides, bearing tolerances, valve-timing diagrams and general mechanical information, and supply it to the shop and to the field force. We believe this assists

in turning the overhauled unit into the field in its original condition as nearly as that is possible. Information of this kind tends to eliminate a constant repetition of mistakes that happen so frequently in this line of work in the average garage or service-station. To give an idea of how we tabulate such information, a sheet on carbureter nozzles on White trucks is reproduced in Fig. 13.

One of the great problems in the operation of a large fleet is to obtain men who understand all phases of this class of work, and can still realize that absolute cooperation with the operating end is essential to success. I believe that the lack of skilled and well-trained help of the various types necessary is a direct reflection on the

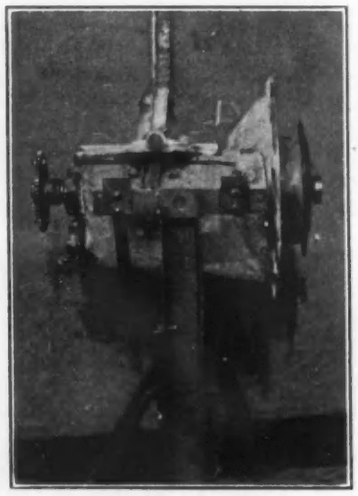

FIG. 11—GEARBOX UNIVERSAL REPAIR STAND

With This Fixture It Is Possible To Work on the Gearbox from Different Positions, the Changes from One Position to Another Being Made Readily

vehicle builders, who have failed to train sufficient men or offer sufficient inducements to the right type of men to enter into a line of endeavor that is sadly lacking in all-round trained personnel. A situation of this kind can and must be cured if builders and operators expect to obtain the maximum economy from a given unit.

ENGINEERING FACTORS AFFECTING OPERATION

We find companies in the commercial-vehicle field stressing one point or another as promoting economical operation. In this field we do not see the yearly rush from one feature to another that we see in the passenger-car class. In the commercial-vehicle field changes are made frequently without notice or with but little notice to the user. This tends to complicate the handling of service, for the user does not know where or when changes have taken place. I suggest that the National Automobile Chamber of Commerce have a standard specification sheet to cover a given type or new model of truck, and supplementary change-sheets that would list part changes or deviations from the original model. One copy should be supplied to the fleet owner, and one copy kept on file at the service-station in the territory to which the truck is delivered. This would assist the fleet owner, and it would assist the service departments of the truck builder by tending to reduce inventories held at service-stations, thus decreasing the labor cost of handling them. Probably nothing is more provoking to the user or embarrassing to the service-station than the selection of the improper part for a given place. Improvement is being noted in this line, but standardization is needed.

TIRE SELECTION

The fleet operator wants a tire unit that will give the greatest mileage, so as to avoid frequent lay-ups of the vehicle for tire changes. He wants a tire that protects the truck mechanism as much as possible, but still delivers satisfactory mileage, one that performs as nearly as possible in the same manner throughout its entire life, so far as its cushioning and tractive properties are concerned. The need is for a tire that provides the maximum possible traction, to eliminate so far as possible the use of chains, and the maximum safety, to eliminate accidents; that is, good non-skid protection. A tire is desired such that, when the original tread becomes worn, it can be re-cut readily to bring back the original properties; one that delivers low tire-mileage cost but not at the expense of mechanical upkeep; one that meets all the foregoing demands and does not need to be replaced before its deflection values are impaired so seriously that impact measurements are abnormal as compared with the original equipment.

Tire equipment affects the repair and the upkeep cost of a truck materially. We can select from three classes: solid, pneumatic and cushion tires. While the pneumatic tire has been advertised widely as giving remarkably easy riding-quality, I have been unable to realize the expected saving in upkeep on trucks of 1½-ton capacity and upward. This appears to be due to the severe reaction of a pneumatic tire when inflated to standard pressures. On some roads, particularly sandy roads having deep ruts, in open fields such as orchards, and on plowed ground, the pneumatic tire gives traction and service second to none; yet, if operated the year round, it is

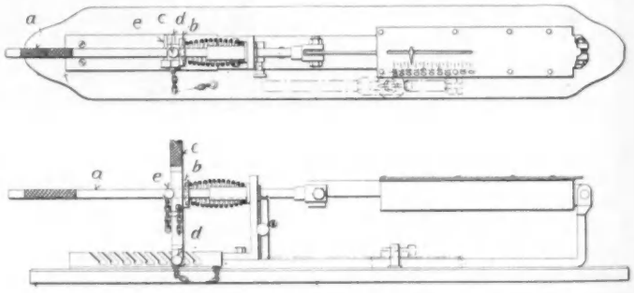

FIG. 12—VALVE-SPRING TESTING DEVICE

This Device, Which Is Attached to the Wall in a Vertical Position at a Convenient Height Is Used To Test the Springs as They Are Removed from Engines That Are Being Overhauled. To Obtain the Best Results from a Given Engine, It is Necessary That the Valve-Spring Pressure Be Maintained. In Operation the Rod *a* Is Pulled Down until the Latch Engages the Notch in the Rod Corresponding to the Spring To Be Tested. The Spring Is Slipped over the Rod Followed by the Washer *b* and the Handle *c*. After the Pin *d* Has Been Inserted, the Spring Is Compressed until the Pin *e* Can Be Inserted in the Hole in the Handle. Now the Spring Is Compressed to Such a Length That It Should Give the Reading Shown on the Scale. Next the Pin *d* Is Removed, Thus Allowing the Handle *c* To Become Free. Releasing the Latch Allows the Spring-Balance To Register the Tension of the Spring. If the Length of the Spring and the Reading of the Spring-Balance Remain the Same as Before, the Spring Is Satisfactory. If the Spring Tension Is 3 Lb. Lower than the Previous Reading, the Spring Should Be Replaced. The Reading for the Various Types of Valve Spring Are Tabulated Below

Valve Spring	Free Length, In.	Deflection, In.	Under Load, Lb.
AC Mack	...	3 5/8	75
	...	4 3/8	85
Pierce Arrow 2 Ton	4 1/2	3 3/8	70
5 Ton	4 1/4	3 3/8	83
White ¾ and 3½ Ton	2 3/4	2 1/4	30
5½ Ton	3 3/4	2 3/4	55
3½ Ton	3 1/8	2 1/2	80
Continental	4 1/16	2 3/8	35
Hinkley	...	3 1/4	65
Dodge	3 3/4	2 1/4	40
Ford	2 7/8	2 1/8	22

subject to rapid cutting and short life during the winter season.

Relatively, the solid tire gives no protection when compared with pneumatic or cushion tires. It permits excessive vibration, is impossible to operate under certain road conditions and usually is unsatisfactory with respect to traction and non-skid qualities.

Some types of cushion tire give the majority of the desirable results enumerated above and are capable of promoting very economical tire and mechanical upkeep costs as compared with past tire experiences. In addition, the employment of this type of equipment should be a great factor in reducing taxation, because of its proved value as a protector of State highways; a fact that is now recognized very generally by State highway departments. Based on tire performances with present-day tires, transportation costs should be lower than such costs were 5 years ago.

INSTRUCTIONS
— White Truck Carbureter —

The following is a list of the different-size standard carbureter nozzles to be used on White truck carbureters functioning on models listed:

GK Motor, Model 15 (¾ Ton) and 20 (2 Ton) trucks

Low Speed	33-25
High Speed	0-40

For Better Mileage:

Low Speed	32-15
High Speed	0-38 or 0-36 (For cold weather)
High Speed	0-34 (For warm weather)

GO Motor, Model 40 (3-3½ Ton) truck

Low Speed	33-25
High Speed	0-40

For Better Mileage:

Low Speed	32-25
High Speed	0-38 (For cold weather)
High Speed	0-36 (For warm weather)

GN Motor, Model 45 (5 Ton) truck

Low Speed	33-25
High Speed	0-42

For Better Mileage:

Low Speed	33-25
High Speed	0-40 (For cold weather)
High Speed	0-38 (For warm weather)

FIG. 13—AN EXAMPLE OF HOW INFORMATION IS TABULATED FOR THE BENEFIT OF THE SHOP AND FIELD FORCES

Sheets Similar to the One on Carbureter Nozzles for White Trucks That Is Reproduced Herewith Have Been Prepared for Pistons, Piston-Rings, Valve-Guides, Bearing Tolerances, Valve-Timing Diagrams, General Mechanical Information and Cushion Tires. The Objects Sought in Their Compilation Are To Assist the Shop and Field Forces in Returning an Overhauled Unit to Service in a Condition That Is as Near Its Original Condition as Possible and the Elimination of the Constant Repetition of the Mistakes That So Frequently Happen in the Average Garage or Service-Station

As to proper fuel to operate our fleet, the products we sell are the ones we use; they are uniform and can be depended upon. We get the greatest efficiency out of the gasoline by studying all conditions pertaining to carburetion. We have specialists who repair and maintain the carbureter in proper mechanical adjustment for a given engine. Waste of motor fuel is eliminated by the use of proper dispensers such as are seen at our service-stations. Engine and chassis lubrication are

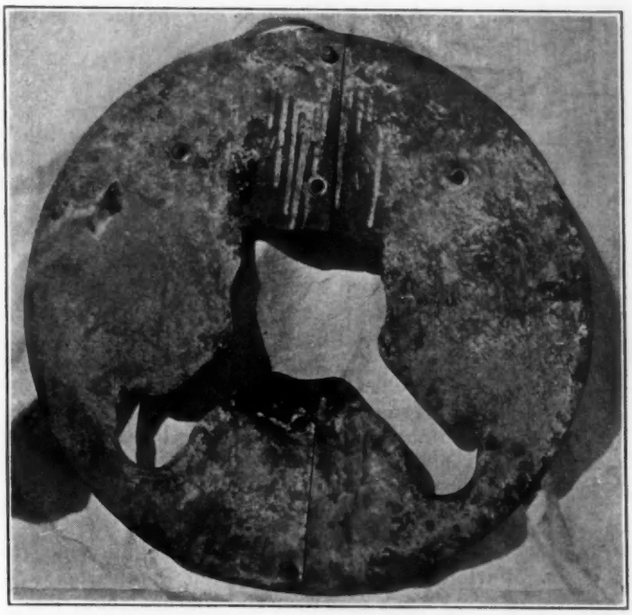

FIG. 14—PAN OR BRAKE COVER FOR A REAR-AXLE

Enclosing the Brakes with a Cover of This Type Has Materially Improved the Operation of the Brakes and Lengthened the Life of the Brake-Linings 800 to 1000 Per Cent

effected by using our special line of lubricants. We follow the charts of recommendations that are drawn up only after a careful consideration of the various factors pertaining to proper lubrication and of the grades of oil we offer. The company's products are being tested out in our development department continuously, from chemical, physical and dynamometer standpoints, supplemented by performance records of our own vehicles and by practical road-tests of various types. Our trucks give

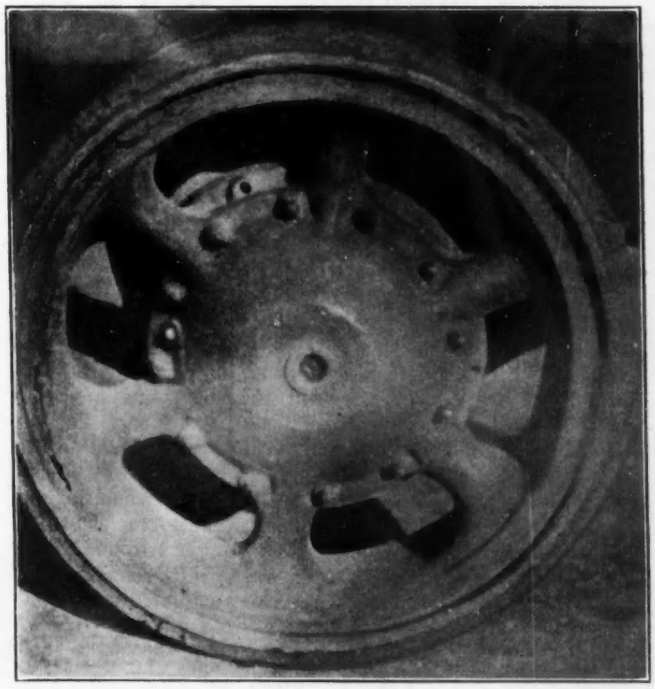

FIG. 15—AN EXAMPLE OF THE FAILURE OF A STEEL WHEEL

This Wheel, Which Had Not Been Subjected to Overloads, Failed after Running 12,500 Miles

great regularity of service, because our products operate the equipment satisfactorily.

Chassis Lubrication

Within the last few years we have seen the grease-cup supplemented largely by other devices and special lubricating systems that provide a more uptodate service. Better lubrication and greater time-saving would result if builders would bring all connections for these devices to the outside of the chassis, to convenient locations, or provide oil wells in the brackets as in the magazine system. In some chassis we still find countersunk oil-holes that are in plain view before the body is on the chassis but are immediately forgotten when the body is installed. A magazine system of lubrication to these and other points, built into a chassis, certainly would lengthen the life of many parts as compared with present methods. Grease-cup elimination, supplemented by new oiling methods, has resulted in a decreased cost of upkeep, but opportunity for improvement still exists.

Brakes

Improvements have been noted in brake-material life and, in addition, devices for its rapid application and proper fastening have come on the market that reduce the amount of labor necessary to make changes. An improvement that can still be made in many models is a better arrangement of the toggles and the levers in some cases and, in others, a closing in of the brake-band to protect it from sand and gravel, a factor contributing to very short brake-lining life in some models. In some cases a builder will enclose the brakes on one model and fail to do it on another. This does not seem to be logical practice. In connection with brakes, a vast improvement has been made in the matter of skid-chain clearance in some models recently, but advances can still be made. Improper clearance frequently results in costly repairs and nasty accidents.

We have found that brake-lining life and the operation of brakes is improved materially by having the brakes enclosed. Fig. 14 shows one design of brake-spider cover that has been employed to advantage on a large number of trucks equipped with a popular type of worm-drive axle. This cover results in greater economies being effected. Under some extreme road conditions, we found brake-linings being replaced after an average of from 400 to 500 miles. Enclosing the brakes by the foregoing method gave 8 to 10 times longer brake-lining life than when the brakes were not enclosed.

Wheels

I have noted, at various times, discussions by the wood-wheel and the steel-wheel manufacturers. As a result, I have watched closely the operation of these two types of equipment and have arrived at the following conclusion: Neither type, if built properly, has any discernible effect upon tire life. The life of each type is dependent upon good workmanship and material. Failures have been noted in each type in as low as 12,000 or 14,000 miles of travel. An example of steel-wheel failure is shown in Fig. 15; the wheel was not overloaded. Metal wheels of some types have a longer life than that of wood wheels. Operators, washers, greasers and painters prefer the steel wheel because of its general construction, which is itself accessible and also allows access to other parts of the mechanism.

Accessories

A rapid improvement has been noted in many articles that the operator is called upon to use. Skid-chain design has improved, and the possibility of changing chains conveniently and rapidly should lengthen tire life. Signal devices have improved materially. Next to the exhaust whistle, which is barred in many localities, the electric horn seems to be the best device to use when batteries are available. The average hand-operated horn on the market today is so frail that it will not stand up under the operator's heel or elbow, so often used instead of his hand. Windshields, which were considered impractical a few years ago, today give comparatively good service.

Cabs should not be classed as accessories, any more than should the body of a passenger car; but, since builders list them as extras, they are reviewed here. Improvements have been noted, but if the various builders would standardize on a design for the various models that could be built from the chassis up, a distinct step would be taken to reduce upkeep costs as compared with the purchasing of this part as an extra. I am much in favor of metal cabs, in preference to any other type. The life and the safety features of a metal cab far offset any objections yet brought to my attention.

Motor-truck electric-lighting equipment is still in its infancy from a standpoint of dependability, as compared with passenger-car electrical equipment. The generator, the head-lamp, the head-lamp brackets and the switches still present great opportunity for improvement. What is needed is electrical equipment built especially to withstand the vibration of motor trucks.

Speedometers, hubodometers and meters of various types have improved materially in design. It appears to me, however, that an opportunity still is afforded for improvement in devices of this class along the line of a mileage and trip-recording device that will stand up under truck vibration and give a ready history of the truck's activities on one record. In addition, better installations should be planned by the truck or the speedometer companies, so that the upkeep will be reduced as compared with that of today. Better location of drives, more substantial gearing and an increased number of supports for the driving-shaft are the points of improvement to bear in mind.

Governors are generally recognized as a necessity and are being insisted upon by law. A governor should be an integral part of the engine; when designed as such it assures both the builder and the user that the maximum results will be obtained with respect to power development and fuel-economy. A governor should be built simply and ruggedly.

Advances have been made along many lines that tend to promote economy in the general transportation field. Many models are new and have features for which varying claims are made. Others, while showing no radical change over a period of time, have profited on account of the field experience of the builder who has incorporated ideas that should promote economy in the newer models. I advocate simplicity and accessibility in design. These points are overlooked too often. It behooves the fleet superintendent to watch for such points and to improve upon the weak ones if it can be done economically, so that the future operation may be conducted at less expense. One point along this line can be noted from an examination of Fig. 16. This shows a change that eliminated a torque-rod. This change tended toward simplicity, did away with the upkeep of a certain part that gave trouble every 5000 or 7000 miles, eliminated the necessity of rebushing that part frequently and avoided the replacement of certain parts of the spring-axle housing every 15,000 or 17,000 miles. By keying

the spring-saddle seat and then brazing it to the rest of the axle-arm, the old part was continued in service and has performed satisfactorily over a distance of from 35,000 to 40,000 miles. Similar change was made in another model of truck, the radius-rods being eliminated and their upkeep obviated.

With regard to accessibility, I mention the need for the attention of engineers to better facilities for changing oil. Changing oil is recommended in practically all cases at certain intervals, yet it is made a difficult task by the majority of engineers, who fail to provide suitable or accessible means for this purpose. Proper provision in all units would certainly encourage this important process and promote longer life. Designers should be careful to take previous practice into consideration, and it behooves any factory organization to keep on file a suitable set of service records or historical facts regarding its products, so that mistakes of the past will be avoided in the future designs. Some of the simple mistakes that have been noted in new models and caused expensive changes indicate to me that this is not done in many cases.

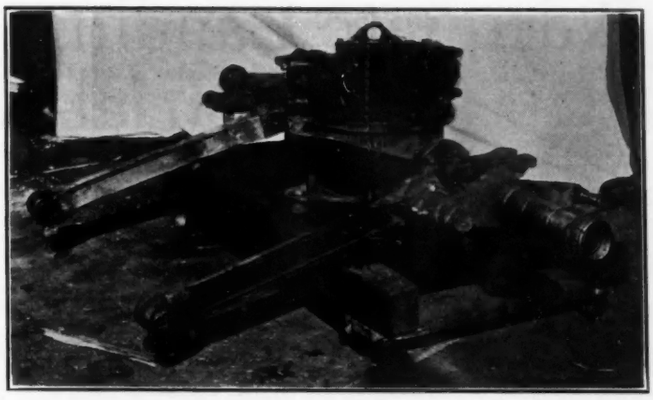

FIG. 16—A CHANGE IN TORQUE-ARM CONSTRUCTION

This Modification of Design That Eliminated a Torque-Rod Tended to Simplicity. By Keying the Spring-Saddle Seat and Brazing It to the Axle Arm the Old Part Was Continued in Service and Has Performed Satisfactorily for 35,000 or 40,000 Miles. The Change Eliminated a Part That Gave Trouble Every 5000 to 7000 Miles and the Need for Rebushing It at Frequent Intervals as Well as Obviated the Replacement of Certain Spring Axle-Housing Parts Every 15,000 to 17,000 Miles

OPERATING COSTS

What happens to the operating costs as a motor vehicle grows older? This depends upon the vehicle, its original price, the service rendered by the company building it and whether it was originally suited to the work. If not suited to the service, it will depreciate rapidly. Two factors that may cause this are overloading and speeding. If it is a model that has been discontinued, loss of time and the high cost of repairs and parts will militate against its use. What kind of a repair organization and facilities have you behind it? Is this organization supplied with good facilities and proper equipment? These are important questions.

With similar facilities for a given job, a motor vehicle 7 years old can be repaired more cheaply today than it could 5 or 6 years ago. We were then passing through a transition stage such as America or the world never saw before; during this time wages mounted rapidly and labor was restless, ever-changing, indifferent and neglectful. Repair processes that then appeared difficult to have performed properly seem trivial today. Now labor is steadier and more productive, and it is possible to maintain an organization. Many repair facilities have been improved. Parts are not as high in price. In addition to this, an operator under average conditions has charged off all parts on a given vehicle for depreciation; so, today, this item alone, set aside as a reserve fund, will more than take care of the running repairs and the periodical overhaul.

Generally, machinery has three periods of extensive upkeep: (*a*) when it is first installed, (*b*) when it is overhauled and (*c*) when it is being run-in after overhaul. Often, new machinery costs more to run in the early periods of its life than in later periods. This is true particularly when the first cost will permit of little time for inspection. Overhaul periods must be determined. No logical reason for the second overhaul being materially higher in cost than the first exists. Good supervision, workmanship and material will obviate this. The third-period costs can be kept to the minimum by good workmanship and operation after the machine is again doing its work.

If a vehicle has been at a station in the hands of a manager and an operator for from 5 to 9 years, and they want this truck back for service, it is indicated that it does not give trouble as compared with when it was new. Why should it, provided the workmanship is all it should be? Such a vehicle should function better today than it did during some of the previous periods of time it was in their hands. In fact, under the unit-repair system, the truck may be equipped with a new engine, a new transmission and a new rear-end, provided these had been added to stock at about the time the chassis arrived for repairs.

RECORDS AND RECORD FORMS

Fleet operators should keep records that give a line on vehicle operation. The records should be as simple as possible, and be divided into the following main headings, which indicate their use:

(1) Output
(2) Time Keeping
(3) Service Stock
(4) Inspection
(5) Tires
(6) Insurance
(7) General Accounting

Probably the two most important points to watch in the records are (*a*) to have before the route foreman promptly the daily output and mileage sheets and (*b*) to have before the shop superintendent the accumulated time daily on the work going through the shop, as well as a system of material checking. These two items are the key to the entire situation. Without them, excessive waste and high costs will creep into fleet operation.

The remainder of the records are necessary for systematic procedure and the elimination of waste. General bookkeeping summaries are available so late that they are really post-mortems. Make sure that these summaries show a profit by keeping the daily summaries uptodate, and in the hands of the man who is in direct contact with the fleet operation. Fleet operation is of such magnitude that it calls for the wholehearted cooperation of all. Many of the ideas and the special tools, expressed, described and discussed here, originated from others in our organization. I wish to give them and all others who have helped me due credit for their part in my work.

Adequate Landing-Fields Will Develop a Commercial-Aviation Industry

By A. A. G. Fokker[1]

Annual Meeting Paper

MR. FOKKER describes the impressions of American aviation that he received on two previous visits to the United States and shows by contrasting them with the impressions he is receiving on this, his third, visit that great progress in commercial aviation has been made here in the last 3 years, especially with reference to the successful performance of the Air-Mail Service and to the fact that the general public and business men in particular have far greater confidence in its possibilities of development than formerly.

Giving instances where additional airplane routes are feasible even now in the United States and instancing the telegraph, the telephone and wireless transmission in proof that when an instrument or a way of communication is created which gives better and faster service it cannot be suppressed, Mr. Fokker gives an account of European aviation development, urges the necessity for attaining ability for aircraft to fly at night and specifies the advantages secured in Europe now by combined over-night railroad-and-airplane service. "Wild" or "taxi" airplane flying is described and spoken of as an imminent possibility and a classification of aerial transport is made that he believes will apply to the future development of the airplane. He asks "Why not more airplane flying?" and says aircraft terminals and facilities are requisite to this accomplishment.

European landing-fields and facilities have furthered aviation development there and have brought increased business to the cities in or near which they are located, specific citations of this are made, the effect of having adequate airplane facilities is enlarged upon and the provision of landing-fields throughout the United States is urged as a present necessity. Future aviation probabilities and the development of aerial traffic are also treated briefly.

DURING my first visit to the United States 3 years ago, I found the general public very skeptical as to the immediate and the ultimate possibilities of commercial aviation. The idea of danger was then uppermost in the minds of the majority of the people. I met many persons, but very few who had any real knowledge of aviation. In general, it was believed that when a person went up in an airplane, that person would fall and die if the engine stopped. That belief was very prevalent.

Following the war, much war materiel was sold; many airplanes were flying that were in dangerous condition and they killed many people. Since the press is always ready to give such matters sensational headlines, such as "Flyer Killed," the public received the impression that aviation is very dangerous; but if an airplane should fly some tremendous distance without accident, say 3,000,000 miles, the newspapers would most probably report it in a small item only, if at all.

Not only did most persons have this idea of danger concerning airplanes, but I was very much astonished to discover how little knowledge of them was possessed by a prominent man in one of the largest industries in America, with whom I had an interesting interview. He said: "Mr. Fokker, how are you moving the wings of airplanes now?" I did not know what to answer, so I said: "Yes, we are moving their wings." I could not give him an answer; I did not expect such a question. But this serves to illustrate that knowledge about aviation was not widely spread. In the speeches I made, I told my audiences that flying is not dangerous, but I could read in their faces "I do not believe it." So, I told them that more persons die in their beds than in airplanes, which is perfectly true.

On my second visit to this Country, in 1923, I was very glad to find prevalent a much more general knowledge about aviation, mainly on account of the splendid results obtained in the Air-Mail Service by the United States Post-Office Department, but also furthered by the fact that influential Americans who were traveling abroad had made full use of the European air-lines and had gained flying experience. Fear was being eliminated gradually by these means and I found that business men were inquiring seriously into the possibilities of aerial transportation and beginning to calculate its probable cost and its influence upon business.

I have been in the United States only on short visits; this is my third. An occasional visitor, such as I am, often is better able to judge the various stages of progress made by an industry than one who, by reason of his very nearness to that industry, is apt to lack the proper perspective. So, I am glad to notice a decided improvement in the general outlook as regards commercial aviation in the United States. Now, I find that interest very keen and that a number of projects are being initiated which have good financial arrangements and a most promising outlook for success, provided their financial backers will carry-on through the inevitable period of infancy and will not lose heart. Manufacturers also must keep step with the times and hold themselves ready to supply the requirements of a growing market with truly uptodate equipment.

All persons acquainted with the automotive industry know that aviation has passed the stage of excessive danger. In Europe, the air-lines are operating with great regularity and safety. The peoples generally know now that airplanes are not only useful in war and for sport but also constitute a new means of transportation. Out of this new means of transportation will grow a new industry. But the support of the large business organizations is needed to convert aviation into an industry.

Additional Airplane Routes Feasible Now

It strikes the casual visitor from abroad that aerial transportation in the United States has not as yet reached the stage of being a part of daily life and a factor in business that it attained in Europe from the very beginning, due, no doubt, to the great familiarity with aircraft of all kinds gained there during the war. And yet, a glance at a railroad timetable for this Country will show that, over many routes between leading centers of population, the *average speed* of even the fastest trains is but little more than one-third that of the commercial airplane of modern type.

[1] Fokker Airplanes, Amsterdam, Holland.

For example, the fastest train between Seattle and San Francisco requires 30 hr. to cover the distance of but 950 miles, corresponding to an average speed of about 32 m.p.h., which an airplane can fly over in 10 hr. or an average speed of 95 m.p.h. Again, I am told that a very heavy traffic is maintained daily between Tulsa, Okla., and Kansas City, Mo., a distance of 260 miles; by railroad, the time required is 7½ hr. between these important cities but, by airplane, the time required should not be more than 2½ hr. Even the traffic between such important centers of population as Detroit, Cleveland, Chicago and Cincinnati does not show a greater average speed on the fastest train than about 42 m.p.h., which is not one-half the speed of an airplane. By using night flying between New York City and Chicago, every letter mailed in the evening in New York City could be delivered in Chicago in the morning; whereas, letters now require at least 24 hr. from desk to desk. The enormous saving of time that is possible by utilizing airplanes is very evident.

Considering the great extent of the United States, its enormous population, its large cities, the numberless travelers and the tremendous volume of freight that must be transported, I am completely astonished that commercial aviation has not developed faster. I am sure that a demand for faster transportation exists. It is inconceivable that a demand for greater speed between the centers of trade mentioned, and between other such centers, should not exist. If the demand has not become insistent, it must be because the railroads have long since reached that practical limit at which additional revenue will not counterbalance the expense of faster trains. Faster service is absolutely demanded by the public in some cases, as is shown by the success of such trains as the Twentieth Century and the Broadway Limiteds, that often are dispatched in several sections to accommodate the traffic. Who can doubt that, if faster transportation facilities were provided between all large cities, an eager public would speedily avail itself thereof? It has been proved absolutely that, if there be an instrument or a way of communication which gives better and faster service, it cannot be suppressed; witness the telegraph, the telephone and wireless transmission.

European Aviation Development

It is not in aerial passenger-transportation, however, that the greatest benefits make themselves felt. From London, different lines operate to the Continent; to Amsterdam, to Paris and to Königsberg. They operate in winter and in summer, giving regular service with a high degree of safety. For example, the Dutch Air-Service between Amsterdam and London uses my airplanes and has now operated for 3 years without having had a single accident. Other lines also are operating with remarkable safety. Statistics show that, on the various air-lines which have been running regularly across the British Channel since the spring of 1921, freight and merchandise traffic has increased in far greater proportion than has passenger travel, especially since the adoption of machines equipped to handle this character of traffic only. This, in turn, enabled the management to reduce the number of trips by carrying larger and larger cargoes, thereby reducing overhead expense.

Night Flying

It has become a truism that the full advantages of aerial transportation cannot be realized unless the distance flown over be so great as to afford an enormous saving of time. In a country such as this, night flying is imperative in the future, for by night flying alone can a saving be made of "business time," which is the only saving worthwhile to the business man. It is very gratifying to learn of the successful experiments that have been made along this line by the United States Air-Mail Service, the results of which will be applied as a feature of its transcontinental route.

Over-Night Railroad-and-Airplane Service

Not only are the European air-lines already mentioned operating with great success, but in some instances long distances are being covered by over-night railroad-service in conjunction with airplane service. Even by such means, some remarkable savings of time are effected. For instance, an all-rail journey between Berlin and Moscow requires 4 days. The service from Berlin to Königsberg is by night train; thence the trip to Moscow is completed in 7 hr. by airplane, accomplishing a 24-hr. service from end to end. A saving of about 1 week is made for a round-trip.

Another line on which a great saving of time is manifest is between Toulouse in France and Rabat in Morocco. The steamer trip on this route requires 5 days but, connecting with a night-train service, an airplane requires only 2 days that include an over-night stop. At Toulouse this route connects with a night train from Paris. This line is used for transporting mail. If we can accomplish the flight of airplanes at night, this will effect the maximum saving of time over long distances.

"Wild" Flying

Last year, what we term "wild" flying developed. For example, suppose a London banker needs to visit many towns on the Continent of Europe. He hires an airplane, starts from London and flies to Paris. He transacts his business, stays as long as he likes and then flies to Madrid or perhaps to some city in Italy, and does likewise. He is not bound by the time-schedules of the air-lines; he is equipped with his own airplane and can fly when and where he likes. I think the encouragement of this "taxi" flying, as I call it, will be the easiest way to develop commercial aviation generally.

Aerial Transport Classification

Machines for aerial transportation can be divided into three classes. I think the small airplane, similar to a "taxi" automobile, will carry two or three persons between cities. When privately owned, it will be used like a private automobile. Later, perhaps, when airplanes become better developed, smaller landing-fields can be used. Country people and farmers will use the small airplanes.

As to my opinion of these small airplanes in regard to engine power, a competition of airplanes having 5, 10 and 12-hp. engines was held in Europe, but I think such low-powered small airplanes will not have much commercial value. It amounts to the same thing, in my opinion, as building a motorcycle with a ½-hp. engine; such a motorcycle can be built and can be ridden successfully on a very good highway, but it does not give the service, the speed and the surplus power needed for all circumstances. I see no commercial worth in airplanes having less than 50 hp., although the small airplanes in question are perhaps all right for one person and possibly for one passenger also.

One of the small cars has a very powerful engine, but you are not using its full horsepower all the time. Ordinarily, you use 25 per cent of the engine power, and

you use approximately 100 per cent of the engine power when in the mountains or when you find yourself in a difficult situation. It is the same with airplanes. You have to use the full power of the engine in starting and stopping. If they are to be used by everybody, that is the main difficulty in using airplanes commercially. You can use them only from a flying field, but you do not need a large field necessarily.

The second class will consist of the larger type of airplane, having an engine of about 500 hp.; it will carry anywhere from 2 to 10 passengers. I think this type will be used on the regular air-lines and that it will carry mail, passengers and freight. We expect to install next year airplane service between London, Amsterdam and Paris, using special airplanes designed to carry freight only. It has been proved to be very unpleasant for passengers to ride along with freight; for example, for a few passengers to sit in a cabin filled otherwise with consignments of ladies' hats and other things that are very light and constitute suitable freight for airplanes.

Then there is a third and much larger type, which is not yet developed but which I am sure will be developed, having engines of 1000 to 2000 hp. or more. It will be used in the very distant future for very long transcontinental and transoceanic flights. I am sure that within 20 years it will not be unusual for airplanes to fly between America and Europe. Considering the enormous quantity of mail sent and received between continents, it can easily be computed that such an air-line will be a splendid, paying proposition when the technical development shall have gone that far. So far as distance is concerned, between America and Europe, that is as nothing to our airplanes now. After the war, one of my airplanes flew from the Atlantic to the Pacific coast and proved that it is possible for airplanes to fly long distances. So, I am absolutely optimistic.

Why Not More Airplane Flying?

But when I study the entire subject, I ask myself: "Why is there not more flying?" Then I come to the main point of my discussion. Suitable airplanes are not being built in America, and landing facilities are lacking. You have splendid industries and splendid engineers who are able to develop any airplane type or any engine to be built for commercial-aviation purposes. I have seen the development of aviation engines in Detroit, the speaker who preceded me described other aviation engines and the automotive industry is working to produce a strong and reliable engine. There is lack of confidence on the part of the public, but the public has nothing to fear. If air-lines are started here, you will get the passengers and the freight just as we do. So, I ask again: "What is the reason you have no commercial flying?"

Aircraft Terminals Requisite

I can see the commercial-aviation situation just as if railroads, bridges, locomotives, sleeping and dining cars had been developed and no railroad terminals had been provided. You cannot use a railroad without having terminal facilities and this is now the position of commercial aviation. Airplanes and pilots are available but there are too few terminals. At the same moment that terminals and facilities become available, commercial aviation will begin; not only in the United States but everywhere.

When a person can fly to a city and leave his airplane on a flying field to be supplied with fuel, greased and put in order, all that person needs to do on his return is to fly back to his starting-point. Then, many people will use airplanes and it is due almost entirely to the lack of such facilities that they are not using them now. It is analogous to having automobiles and no garages, no service-stations and no filling-stations. Just as you increase such facilities, you increase the use of automobile transportation. Therefore, I throw all the weight of my discussion on this point of increased airplane facilities. I am studying this matter in Europe.

European Airplane Facilities

The commercial-aviation situation in Europe was easier to develop. We had a military flying field in practically every country, following the war, and we could utilize all these fields and all the facilities for commercial-aviation purposes. To begin, army airplanes were used, but comfortable commercial airplanes equipped with all facilities were developed very soon. In the cabins of our new airplanes, you can sit in big chairs, smoke, read, talk and have all the facilities you need. It is as comfortable as traveling in a Pullman car. It is not even necessary to wear special clothing.

Effect of Adequate Airplane Facilities

A striking example of the necessity for airplane facilities was evident in Holland, which did not enter the war and consequently had no flying fields. Flying fields were located in London, Paris, Brussels, Antwerp, Berlin and Copenhagen, but none in Amsterdam and Rotterdam. So that Holland should not be behind in commercial aviation, the first necessity was to construct a flying field.

Rotterdam, which has one of the largest harbors in Europe, realized the need of having an airport and built a flying field. It is the only airport in Europe that has been constructed entirely for the purpose of commercial aviation. It is near the city and has good communication with it. This far-sighted procedure has made Rotterdam the center of the air-lines. Amsterdam was not so quick in its decision, and it lost a good opportunity. Because Rotterdam was first to build a flying field, Rotterdam got the business.

Not only did Rotterdam get the business that goes with an airport but it will get the business of the airplane industry. My airplane plant is in Amsterdam but, because of the lack of good flying-fields and facilities there and for the reason that the business of airplane building is increasing very greatly in Europe, I will move my plant to Rotterdam next year. Not only will my plant be moved there but thousands of workmen will move there also and this industry will be lost to Amsterdam. So, it is not alone a matter of commercial aviation development, but the industry will follow to wherever the facilities are located.

First Aid to Future Commercial Aviation

The first thing for you in the United States to do is to concentrate all your efforts upon constructing the necessary flying-fields in all the most needy cities. If such fields all become available at the same time, commercial aviation will develop and it will develop into an industry.

Perhaps I may be looking far into the future, yet you all know that it will be within the lifetime of many of you that regular transoceanic aerial service which will enable a letter to be delivered in London or Paris on the second day after having been mailed in New York City

(*Concluded on p.* 510)

Vol. XIV May, 1924 No. 5

Hot-Swaging of Rear-Axle Shafts

By R. A. DeVlieg[1]

Annual Meeting Paper *Illustrated with* Photographs and Drawings

AN intensive study of all the difficulties of hot-swaging axle-shafts by machine resulted in the conclusions that this method would be most economical and satisfactory if the maintenance costs due to the machines were held within suitable limits by improving their design and construction. Rolling, forging with steam hammers and turning were the three other methods considered, but laboratory tests show that swaging has improved the physical properties of this company's axle-shafts at least 15 per cent.

Following an illustrated description of the machines used and their mode of operation, difficulties attendant upon their development are recited. Among these, the failure of an air-operated collet to hold the bar against the twisting strain necessitated its replacement by a special quick-acting chuck having high-speed-steel inserts in its jaws. The braking mechanism for slowing-down the head was inadequate and additional braking-capacity was provided by using a copper-lined brake-band. Careful application of this brake is necessary to avoid excessive twisting of the hot axle-shaft, but the tendency to twist the shaft was reduced by providing an exact amount of clearance in the dies and shimming them with plates of varying thickness. Rapid wear of the outer bushing and the rollers in the head was overcome by filling the head with lubricating grease and changing it frequently; the front bearing also was lubricated with grease.

Swaging machines should be considered as forging machines rather than as machine tools and given more frequent attention and adjustment than the latter receive. Excessive twisting due to overheating of the stock or to operative carelessness in applying the brake to the head, often reaching one to three turns in the over-all length of a shaft, does not reduce appreciably the elastic-limit or the tensile-strength of the shaft as proved by laboratory tests.

IN a recent effort to determine the most satisfactory method of producing rear-axle drive-shafts of the conventional design, from the standpoints of quality of the finished product and the production cost, the results of an investigation indicated that the hot-swaging process offered rather attractive features. Swaging machines have been in use for several years, but the practice of hot-swaging is comparatively new. Hot-swaging has presented some very difficult problems not encountered in cold-swaging.

Based on estimates and information furnished by the machine-tool builder, the cost of producing axle-shaft forgings by this method appeared to be lower than that of any other method that came under our observation. Our actual experience since we have had the machines in operation has shown that the hot-swaging method would be, without doubt, the most economical and satisfactory if the maintenance cost on the machines were reduced materially. After an intensive study of all the difficulties involved, we have concluded that this can be done by improving the design and the construction of the machines so that frequent breakdowns, resulting from excessive vibration and other causes, will be reduced to practical limits. In reaching this conclusion we have considered the rolling method, which is the one used most commonly; second, forging with steam hammers; and third, turning from bar stock in the most improved turning-machines that have been offered. In addition to the apparent reduction of manufacturing costs, the very important factor of increased strength of the swaged shaft over that of shafts produced by other methods must be considered. Our laboratory tests show that the physical properties of the shaft are improved at least 15 per cent by swaging them.

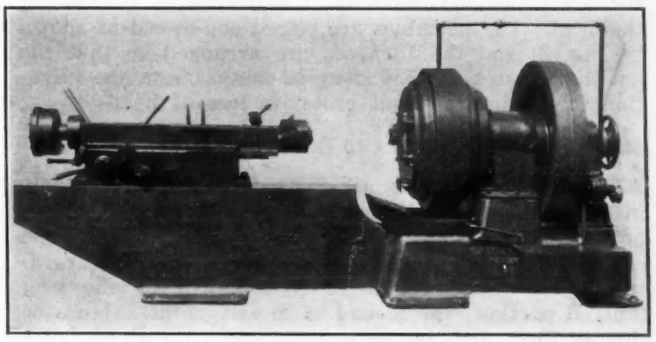

FIG. 1—SWAGING MACHINE USED IN THE PRODUCTION OF REAR-AXLE DRIVE-SHAFTS

In this Machine a Heavy Flywheel That Also Serves as the Pulley for the Belt Drive Is Mounted on the Spindle Which Has a Rectangular Hole at Right Angles to Its Center Line in Which the Dies Are Set. Each Half of the Die Is Backed Up by a Hammer Block That Has a Roller Inserted in the Side Opposite the Face in Contact with the Die. As the Spindle and the Dies Rotate, the Latter Are Forced Open and Closed as the Rollers in the Hammer Blocks Come in Contact with a Series of 12 Rollers Spaced at Equal Distances around the Circumference of the Cage. Since the Cage Is Free To Rotate in a Heavy Hardened Bushing the Force of the Blows as Applied to the Rollers Can Be Distributed over the Entire Circumference of the Head. With the Spindle Rotating at 225 R.P.M. and 12 Rollers in the Cage, the Dies Are Struck 2700 Blows per Minute

Types of Machine

The operation of swaging machines is very simple and is well known. In the machines we have, one of which is illustrated in Fig. 1, a heavy spindle is provided on which a heavy flywheel is mounted that is used also for the belt drive. The head-end of the spindle has a rectangular hole at right angles to its center-line in which the dies, made in halves, are set. Each half of the the die is backed-up by a hammer block that has a roller inserted in the side opposite the face in contact with the die. The spindles run at a speed of 225 r.p.m., forcing the dies to open and then to close as the rollers in the hammer blocks come into contact with the series of 12 rollers that are spaced equally in a cage or separator. This cage is free to rotate in a heavy hardened bushing so that the force of the blows as applied to the rollers can be distributed over the entire circumference of the head. At 225 r.p.m. and with 12 rollers in the cage, blows are struck with the dies at the rate of 2700 per min.

The opposite end of the machine is provided with a slide that is operated by a star wheel through a rack and pinion. The shafts, heated to a forging heat, are

[1] M.S.A.E.—Tool engineer, Maxwell Motor Corporation, Detroit.

held in a special chuck as shown in Fig. 2 and are fed into the dies by the star wheel. As the shaft enters the die it has a tendency to rotate at the same speed as the head; therefore, it is necessary to restrict the speed of the head in which the shaft is held by a brake. If the shaft rotated at the same speed as that of the head, no swaging effect would be produced.

The three machines we have do not differ in their general design from those used formerly for cold-swaging, except for the attachments that are required for our particular shaft and the provisions for cooling the head. The machines are placed end-to-end as shown in Fig. 3, and the furnaces are arranged so that the hot shafts can be passed along in chutes, from one operation to another, without excessive loss of heat.

Operations Required and Difficulties Encountered

Three operations are necessary to produce the shafts in large quantities. Where production requirements are not so great a lesser number can be used because the change in set-up is made very easily. The first operation is to swage approximately one-half of the long tapered portion; the second is to swage the balance of this portion; and the third is to swage the short taper or wheel end of the shaft. The successive steps are illustrated in Fig. 4.

The swaging method reduces to the minimum the amount of stock required to make the forging, because it is necessary to provide only for a variation in length of approximately ¾ in. on the small end of the shaft; there is no waste other than this. The diameter of the bar used is approximately 1/16 in. greater than the diameter of the finished forging and the bar is several inches shorter. In the first operation it is necessary to heat the bar over its entire length. Here most of the trouble develops. The difficulty of holding the bar in the tail-stock chuck against the twisting strain was also encountered. The machine was furnished with an air-operated collet that soon failed because of the drawing of the temper of the collet by the hot bars. Collets made of high-speed steel were tried but, during their short life, it developed that something more positive than an air-operated chuck was needed to withstand the turning strain exerted on the bar while it was being fed into the dies. Special quick-operating chucks with high-speed-steel inserts in the jaws were then used. These chucks are made with two stationary jaws having serrated faces and one movable jaw on which the serrated face is eccentric with a pin on which it is mounted. The bar is placed in the chuck and, as it is fed into the dies, it begins to rotate; this causes the eccentric jaw to grip it firmly. When the shaft shrinks in cooling, this jaw closes in automatically, and the bar is held securely throughout the operation. The operator releases the grip by striking a projection on the eccentric jaw with a hammer.

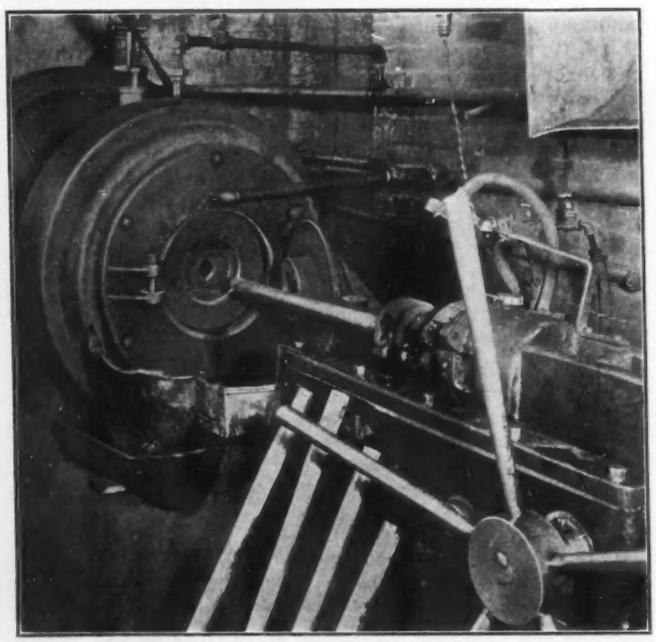

Fig. 2—The Tailstock End of the Machine
After Being Brought to a Forging Heat, the Shafts Are Held in a Special Chuck That Is Mounted on a Slide and Are Fed into the Dies by Turning the Star Wheel that Actuates the Pinion Engaging with the Rack on Which the Slide Is Mounted. As the Shaft Enters the Dies It Has a Tendency To Rotate at the Same Speed as the Head, Which Would Not Produce Any Swaging Effect and It Is Therefore Necessary To Restrict the Speed of the Tailstock by Applying a Brake

Braking Mechanism

The braking mechanism for slowing-down of the head was inadequate, and additional braking capacity was provided by a copper-lined brake-band of standard construction. We then found that if the speed of rotation of the bar was restricted too much the shaft twisted. Careful application of the brake by the operator is therefore necessary to avoid excessive twisting. In this operation, although the dies are approximately 14 in. long, all the swaging is done at the front end as the bar is being fed in. These dies are made so that they can be turned end-for-end to avoid too frequent re-sinking. It developed also that the tendency to twist the shafts was reduced by providing the exact amount of clearance required in the dies. Means for taking up the dies to adjust them for size are provided in a series of plates of varying thicknesses used as shims.

Water Connections and Lubrication

The machines were provided with a water connection at the rear end of the hollow spindle, the theory being that the water fed into the head in this way would be thrown out by centrifugal force through the hammer blocks and the rollers and drained at the bottom of the head. However, it developed that the water was striking the end of the hot bar as it was being fed in and cooling the bar rapidly enough to interfere with the operation of the machine. To overcome this difficulty, it was necessary to change the water connections so as to feed the water directly into the head at the top.

No means for lubricating the rollers in the head had been provided, and it soon developed that the wear on the outer bushing and on the rollers was very excessive because of the speed and the high pressure under which they were operating. The head was then filled with lubricating grease; the machines have been operating in this way for several months. It being necessary to refill the head with grease rather frequently, we are now trying out special heat-resisting grease to improve this situation.

One serious difficulty with this machine is the excessive wear of the front bearing. I believe it to be caused by the leaking in of water and small particles of scale. This is a bronze bearing lubricated with grease from compression cups. This bearing was first lubricated with oil carried over the spindle by a chain from a well. This did not prove satisfactory and we were obliged to change to grease. The grease helps to keep the water and the scale out, but the spindle and the bearing design

at this point can be improved greatly. After a comparatively small amount of wear in this bearing, the spindle drops below the center and, in doing so, takes up the clearance between the dies and the roller cage and causes the cage to rotate at the same speed as that of the spindle. When this occurs it becomes evident, because the operator finds it difficult to feed the bar in and, as no adjustment is provided, the bearing must be replaced.

Second and Third Operations

The second operation differs from the first in that the work is fed through the dies to a stop before the dies are closed in. The remainder of the long tapered portion is swaged in this operation, leaving the larger diameter for the splined end. The dies are tapered on the back face and the hammer blocks are tapered also. When the work has been fed through the dies to the fixed stop, the dies are closed in by a lever that pushes them toward the rear of the spindle along their tapered sides. In this case the force of the blows is distributed more evenly over the length of the dies.

The third operation, in which the wheel end of the shaft is swaged, has worked out very well because of the lighter loads to which the parts of the machine have been subjected. This has led us to believe that, in the other operations, the machines have been operated beyond their normal capacity and that, to make the method a complete success, it would be necessary only to use heavier machines with those changes in construction that have been developed. However, in the matter of upkeep it is apparent that a hot-swaging machine should be considered as a forging machine rather than as an ordinary machine-tool; that such a machine requires more attention and more frequent adjustments than does the average machine-tool.

Die and Roller Material

On account of the severe service to which the dies and the rollers are subjected, ordinary high-carbon steel is not satisfactory material for them. A number of high-carbon steels supposed to be especially suitable for both dies and rollers were tried out. In some cases the dies would swage only a few shafts before checking badly or breaking. The rollers would soon pound out-of-round in some instances and in other instances would chip badly. The steel we are now using in the dies has proved satisfactory; we are able to average from 5000 to 6000 shafts to a set of dies in the first two operations and as high as 10,000 shafts in the third operation. The life of the rollers also has been increased considerably with the steel we are now using.

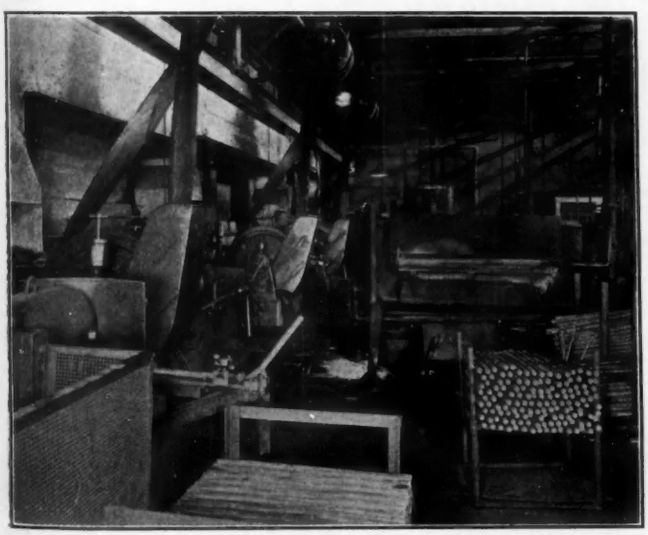

Fig. 3—The Three Machines Required To Swage a Shaft and the Furnaces Are Arranged So That the Hot Shafts Can Be Passed from One Operation to the Next without an Excessive Loss of Heat

The First Operation Is To Swage Approximately One-Half of the Long Tapered Portion, the Second Is To Swage the Remainder of This Portion and the Third Is To Swage the Short Taper or Wheel End

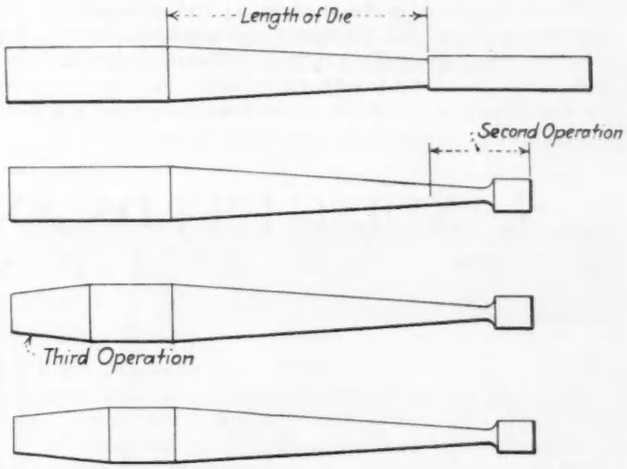

Fig. 4—Successive Steps in the Production of a Hot-Swaged Rear-Axle Drive-Shaft

In the First Operation, Which Is Shown in the Top Drawing, the Dies, Which Are Approximately 15 In. Long, Work on the Front End of the Bar as It Is Being Fed In. The Second Operation, in the Upper Middle View, Completes the Tapered Central Portion. In the Lower Middle Drawing the Third Operation, or the Swaging of the Short Taper or Wheel End of the Shaft, Is Illustrated. The Bottom Drawing Shows the Shaft as It Leaves the Machine

Production Results

The average production in the first operation is 60 shafts per hr., in the second 70 per hr. and in the third 80 per hr. An operator and a heater were employed in each operation. To date, we have swaged approximately 125,000 shafts. A careful analysis of our costs indicates that, in spite of the many difficulties we encountered and the high upkeep cost on the machines, we were able to decrease our manufacturing cost considerably. The only objection to the swaged shaft that has come to our attention is the twisting of the shaft while the bar is being fed into the dies. In extreme cases I have seen as many as six complete turns in the length of the shaft. This excessive twisting is due to overheating the work or to carelessness on the part of the operator in applying the brake to the head. It is not unusual to have the shafts show a twist of from one to three turns in their length. However, laboratory tests have failed to show any reduction in the elastic-limit or the tensile-strength of the shafts on this account.

The advantages lie entirely in the increased strength of the swaged shaft over that of shafts produced by other methods and in the comparatively low production cost. Rather than make a definite recommendation to those who are interested, however, I suggest that they make a very careful study of the method and also that, in the event its adoption is considered seriously, they be prepared for the development of the many little devices that are necessary to the successful operation of the machines. No experienced operators who know the peculiarities of hot-swaging will be available until the method is used more commonly.

No accurate data to determine the stresses on the various parts of the machines are available as yet, but I believe that the practical tests to which our machines and those in other plants have been put have enabled the machine-tool builder to offer machines that are more suitable than were those available heretofore.

The record of the performance of hot-swaging machines is not unlike that of many other types of machine tool in which the stresses on their component parts have been very difficult to calculate, and their fitness for service has been determined by practical tests on the part of the user.

LANDING-FIELDS AND THE COMMERCIAL-AVIATION INDUSTRY

(*Concluded from p.* 506)

will be an everyday occurrence and that the resulting influence in quickening business activity and bringing the nations on either side of the ocean into closer bonds of friendship and mutual trust will be incalculable.

But it is obvious that, if aeronautical development in this Country is ever to take place along the broad comprehensive lines that the geographical conditions and the greatness of the Country warrant, it is the prime duty of every community and of every business organization to make that development possible by providing in time the terminals that are even more necessary to air travel than stations are to railroads or docks to steamships. And when I say "air travel," I do not mean, necessarily, travel by airplane alone; for it is possible that the lighter-than-air vehicle may some day be brought to such a state of perfection as to warrant the faith that its sponsors are trustfully placing in its possibilities.

Dirigibles may become useful for commercial aviation but at present the large airships are very difficult to handle in a storm and more than one will be destroyed during the development process; however, I am fairly sure that the engineers will develop the airship so that it can be used for long-distance flight just as we use airplanes. But dirigibles never will supplant the airplanes; nor will the airplane supplant the dirigible.

Future Probabilities

Twenty years ago, practically no automobiles were in existence. Had we been together here then and had I predicted that every fifth man in this city would possess an automobile in 1924, that Detroit would be using 200,000 automobiles, you would have laughed at me. You would have believed me over-optimistic and might have asked: "Where would we put 200,000 automobiles?" But that is one of the questions you have to answer now.

I am actually speaking in Detroit and I ask: "How many airplanes will Detroit have 20 years from this date per 1000 of its inhabitants?" If I say that 1 airplane will then be operated and maintained for each 1000 people, that does not seem very optimistic, yet, according to population statistics, that would require 1000 airplanes. Think of the facilities required for 1000 airplanes! It would mean not one but several flying-fields for Detroit alone.

Development of Aerial Traffic

Whether for airplane or dirigible, we must have landing-fields. A city can no longer be counted progressive and willing to keep step with the advancement in transportation and in wealth unless the vital facilities are provided that will enable the coming development in aerial traffic to be cared for adequately. It has been my pleasure to note considerable progress along that line during my visits to this Country, but it is not enough to have only the large and prosperous cities so equipped. It is chiefly from the smaller cities and the rural communities that the great number of future private owners of aircraft will be drawn, and it is to them that the aircraft industry must look if its ambition to rival, and perhaps supplant, the phenomenal growth of automobile development is to be realized. These considerations are the keys to successful commercial aviation and to the creation of a commercial-aviation industry.

HELIUM

HELIUM was discovered and experimented with about 30 years ago by the eminent British chemist, Sir William Ramsay, and its adoption by the United States authorities for the filling of airship envelopes is the first and only practical use to which it has been applied. Helium is the next lightest known gas to hydrogen and is remarkable as being the most inert of all the elements. It does not burn or support combustion; it has no taste, color or smell; and so far as is known, it does not enter into chemical combination with other elements. It is present in extremely small quantities in the atmosphere and is found mechanically retained in many mineral earths that are radioactive in character and particularly in thonanite, a mineral earth obtained from Ceylon. It is present in mineral springs and also in the natural gases that arise from wells in many parts of the United States and Canada. It is from this last source that the United States Government is obtaining the supplies for its airships. During the war it was frequently reported that the Germans were preparing to use it in their airships. Probably on account of the rarity of the sources of supply, the lack of knowledge as to its preparation on a large scale and the high cost of its production, it was never so used, a fortunate circumstance for the populations of the Allied towns that were within reach of the activities of the Zeppelin raiders.

The American authorities commenced their experiments on its production in large quantities early in 1917, and by the autumn of the following year had erected a plant for its extraction from natural gases containing about 1 per cent of helium. The plant was found capable of producing about 8000 cu. ft. per day, at a cost of about 10 cents per cu. ft. or roughly 20 times that of hydrogen. The process that was employed subjected the natural gas to compression, by which all the gases present, except helium, were liquefied. The helium passed over and was collected in suitable vessels. The process was in two stages, the helium obtained from the first stage having about 70-per cent purity, which in the second stage was increased to 92 or 93 per cent. It is now stated that either a new process has been devised or the old method so improved that in a single stage helium of sufficient purity for use in airships can be obtained at a cost of about 10 times that of hydrogen.—*Engineering.*

Desirable Road-Illumination

By C. A. MICHEL[1]

Illustrated with PHOTOGRAPHS AND DRAWINGS

INTEREST in automobile head-lighting is ever increasing. The subject is receiving attention today as it never has in the past from all those involved, the manufacturers, the State enforcement authorities, the Society of Automotive Engineers, the Illuminating Engineering Society and the public; and it is very natural that it should for, with our ever-increasing traffic, the question of safe night driving becomes exceedingly involved. From the viewpoint of safety and comfort, the subject of desirable road illumination is equally as important as the much discussed four-wheel brakes and balloon tires. Before the advent of four-wheel brakes and balloon tires, comparatively few car-owners avoided night driving due to fear produced from inadequate braking or to discomfort from high-pressure tires, but many motorists have avoided in the past and still continue to avoid driving their cars at night on account of the inadequate road illumination from their own headlamps and the troublesome glare conditions produced by the lights of other automobiles.

These present-day road and traffic conditions, which are the direct result of head-lighting, present a problem that is demanding for its solution the cooperation of all concerned. Overcoming undesirable glare conditions and at the same time providing adequate road illumination for the car driver cannot be accomplished effectively unless the car builder, the lamp manufacturer, the car-owner and the State enforcement authorities all recognize their respective responsibilities. The ultimate ideal, of course, is the possibility of drying at night with the same degree of comfort and safety that is enjoyed during the daylight hours. Such an ideal can be approached only by conscientious and diligent effort on the part of all those having responsibility.

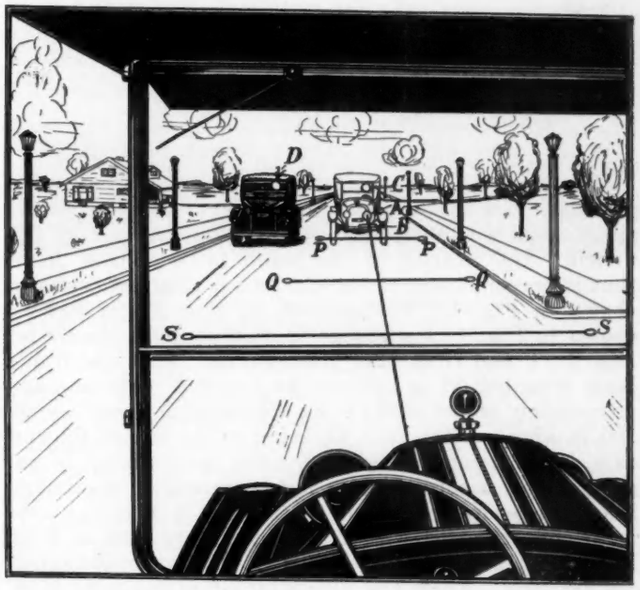

FIG. 2—LOCATION OF TEST POINTS AS SEEN BY THE DRIVER
This Illustration Brings Out More Clearly the Relation of the Points Shown in Fig. 1

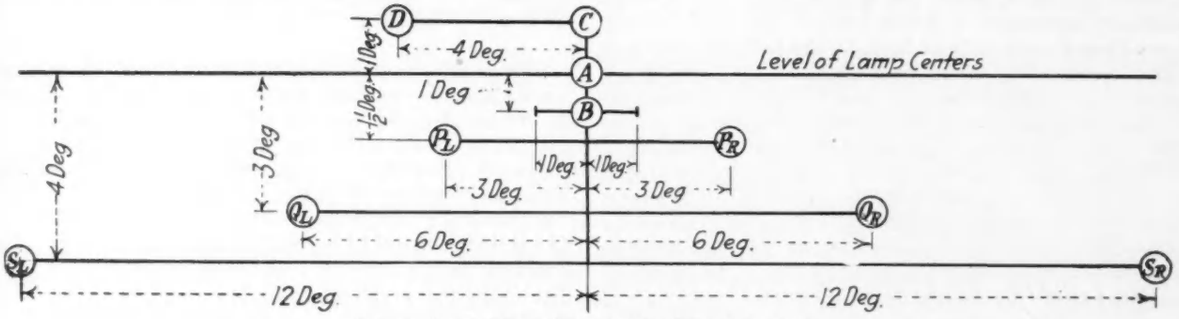

FIG. 1—DIAGRAM OF LABORATORY TEST-POSITIONS
All of the Points Shown Lie in a Vertical Plane That Is Perpendicular to the Car Axis and Are Located in This Plane at Various Angles with the Car Axis. The Permissible Beam-Candlepower Values Adopted by the Society for These Points Are Given in Table 1

LABORATORY APPROVAL-TEST SPECIFICATIONS

In many States throughout the Country legislation has been enacted with the purpose of improving headlamp road-illumination and eliminating objectionable glare conditions. Fortunately for all concerned, it has been the tendency on the part of the State enforcement officials to standardize head-lamp beam specifications. In many States, where head-lighting device approvals are required, the laboratory approval-test specifications that were developed by the Society of Automotive Engineers and the Illuminating Engineering Society for regulatory purposes, have been adopted. These values, which are listed in Table 1, give permissible beam-candlepower tolerances.

TABLE 1—LABORATORY-TEST SPECIFICATIONS FOR REGULATORY PURPOSES

Point	Beam Candlepower Maximum	Beam Candlepower Minimum
A	6,000	1,800
B	....	7,200
C	2,400	800
D	800	....
P_L	....	5,000
P_R	....	5,000
Q_L	....	2,000
Q_R	....	2,000

[1] M.S.A.E.—Chief engineer, Guide Motor Lamp Mfg. Co., Cleveland; chairman, lighting division of the Standards Committee.

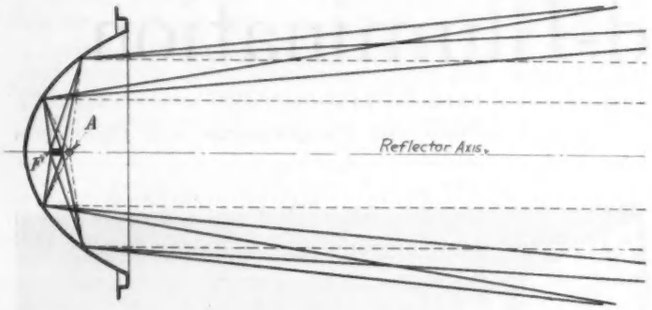

FIG. 3—DIVERGING RAYS REFLECTED FROM A PARABOLIC REFLECTOR When the Filament *F* of the Lamp Is Brought behind the Focal Point *A* the Rays Diverge

It is important to secure an understanding of these specifications as a foundation for the remainder of the article. The location of the points on a vertical plane that is perpendicular to the car axle is diagrammatically shown in Fig. 1. The relation between the points as shown in Fig. 1 is probably illustrated more clearly by Fig. 2. *C* and *D* are the glare points. With the head-lamp mounted 36 in. above the roadbed, they are approximately at the level of the approaching driver's eyes 100 ft. ahead of the car. *D*, being to the left of the car axis, is the point through which the approaching driver passes and, accordingly, a low permissible maximum beam-candlepower has been specified. A higher maximum and, in addition, a minimum are provided at *C* to insure some light to reveal pedestrians and overhanging obstructions. From the viewpoint of glare only, it is most comfortable for the oncoming driver to drive against a beam having an absolute cut-off where no light whatsoever projects above the *A* line, but such a beam is decidedly hazardous to drive behind, inasmuch as objects are then visible only as high as the level of the lamp centers.

As an illustration, the eye has not been trained to detect quickly a pedestrian if he is only visible up to the knees, which fact makes it essential to require some light above the cut-off so that the driver can discern an entire object as he would view it ordinarily. On the same basis, it is evident that overhanging obstructions must be illuminated. If the driver behind the head-lamps were the sole one to be given consideration, light above the cut-off would be increased indefinitely; but, by so doing, the original intention to control the light and eliminate glare must be lost entirely. Hence a maximum must also be specified at *C*. Point *A* is directly ahead at the level of the head-lamps on the car axis. Here a maximum beam-intensity is imposed. As a car travels, irregularities in the roadbed cause it to bounce up and down, even when traveling on a comparatively smooth surface; the result is that the head-lamp beam fluctuates with the car and, if excessive intensities were permitted at *A*, the opposing driver would be compelled to drive against intolerable flashes of glare. With the head-lamps mounted 36 in. above the roadbed, the *B* point is 172 ft. ahead of the center of the car. On the same basis *P* is 114 ft. ahead and 6 ft. to either side of the car axis; *Q* is 57 ft. ahead, 6 ft. to either side, and *S* is 43 ft. ahead, 9 ft. to either side. *B*, *P*, *Q* and *S* are the roadbed illumination points. Theoretically, since *A* is directly ahead at the level of the head-lamp centers, all light on the *A* line is directed parallel to the roadbed; all light below the *A* line will be projected on the roadbed and will help to illuminate it, thus making it necessary to specify minimums only at the *B*, *P* and *Q* points for legal purposes. The *S* point is not listed in Table 1, inasmuch as it was not deemed essential at the time regulatory beam specifications were drawn up.

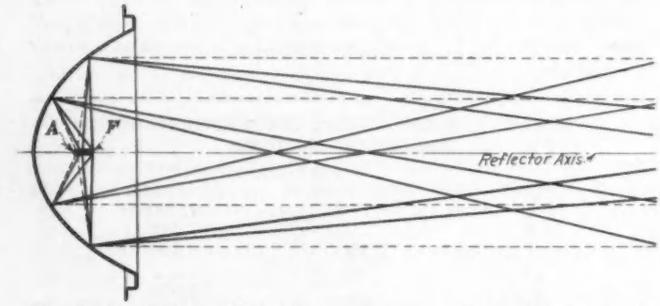

FIG. 4—CONVERGING RAYS REFLECTED FROM A PARABOLIC REFLECTOR If in Focusing a Head-Lamp Filament *F* Is Moved Ahead of the Focal Point, the Reflected Rays Will Cross

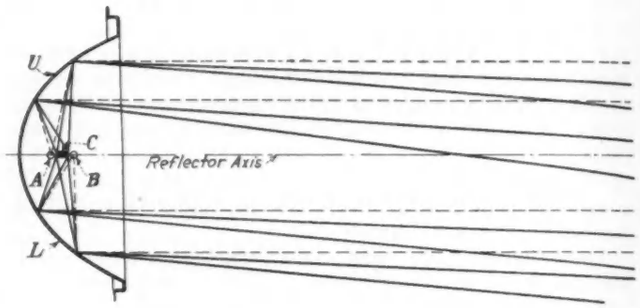

FIG. 5—DISTRIBUTION OF LIGHT FROM A REFLECTOR HAVING TWO FOCAL POINTS In This Reflector, *A* and *B* Are the Respective Focal Points of the Upper and Lower Halves, *U* and *L*, of the Reflector and the Lamp Filament *C* Is Located between Them. This Results in the Rays Being Directed either Parallel to the Reflector Axis or in a Downward Direction

The beam-candlepower values assigned to the various points are the result of careful consideration on the part of competent engineering experts. They represent the essence of data obtained from innumerable road-tests made over a wide range of road and climatic conditions. The specifications at the *A*, *C* and *D* points are inflexible for reasons given above. The values listed at *B*, *P* and *Q* represent the minimum illumination necessary for the average driver who is negotiating average road conditions at moderate speeds. It should be borne in mind that these minimum roadbed-illumination specifications represents minimum requirements only for regulatory purposes and are not intended to indicate desirable illumination. The values as listed in Table 1 form the basis of approvals in practically all States where approvals are required for head-lighting devices. In California, however, the requirements at the *C* point differ in that 500 cp. minimum and 1500 cp. maximum are specified.

As stated previously, the values listed in Table 1 represent the necessary minimum illumination at the road points. If these values were to be duplicated for the average car-owner, he would, in all probability, not be the least bit enthusiastic about his head-lighting and rightfully so, for practically all legal devices comfortably exceed the road-point specifications. Now, to differentiate between permissible road illumination and desirable head-lighting, the Society of Automotive Engineers has set up a list of beam specifications that is directly comparable to the points listed in Table 1. These specifications were formulated as an ideal intended to guide the head-lighting device manufacturer when designing and developing new equipment. They

are considerably more stringent in their requirements and boldly suggest a beam having a definite type of distribution. The beam-candlepower values of these specifications are listed in Table 2.

TABLE 2—LABORATORY-TEST SPECIFICATIONS FOR DESIRABLE ILLUMINATION

Point	Beam Candlepower Maximum	Minimum
A	6,000	2,000
B	....	25,000
C	2,400	800
D	800	....
P_L	....	10,000
P_R	....	10,000
Q_L	....	4,000
Q_R	....	4,000
S_L	....	500
S_R	....	500

Specifications for Desirable Illumination

The points given in Table 2 are located the same as is shown by Figs. 1 and 2. It will be noted that the values at the glare points are practically identical with those in Table 1 inasmuch as the conditions governing these points are fixed. The road-illumination points, however, are increased materially. To start with, to specify some light near the car and to encourage deeper beams with greater lateral spread, a modest minimum of 500 cp. is specified at the S points. Then, at the Q points, the former minimum has been comfortably increased to 4000 cp., which is twice the original amount, and a maximum of 8000 cp. has been added to indicate that it is inadvisable to get too much illumination close to the car. Light can be used to better advantage above the Q points; therefore, the maximum specification. The minimum value at the P points has also been doubled, increasing it from 5000 to 10,000 cp., but at the B point the former specification of 7200-cp. minimum has not been merely doubled or even tripled, but has been increased to 25,000 cp.

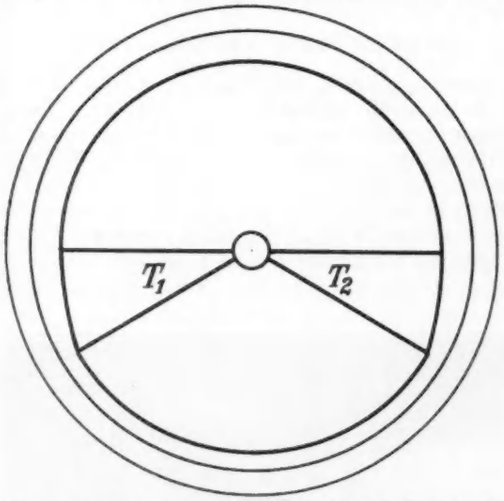

FIG. 6—HOW A CONTINUOUS REFLECTING SURFACE IS SECURED IN THE REFLECTOR SHOWN IN FIG. 5
The Difference in the Focal Lengths of the Two Halves of the Reflector Results in Each Portion Having a Different Curvature. The Two Transition Surfaces T_1 and T_2 Are Provided To Join the Two Halves of the Reflector and Give a Continuous Surface

Careful study of these desirable-illumination specifications clearly indicates the necessity of designing a headlighting device to give a beam distribution that has the maximum intensity near the top of the beam. The greater the distance one wishes to see, the greater must be the intensity of the beam. In legal automobile headlighting where the top of the beam can be no higher than the level of the head-lamp centers, it is that portion of the beam immediately below the top which strikes the roadbed at the greatest distance and, accordingly, it is highly desirable to have a high intensity in this portion of the beam for long-range vision. Good design, therefore, demands a distribution having the highest intensity at the B point and grading down to the lower intensities at the bottom of the beam, the bottom being the portion that strikes the roadbed nearest to the car.

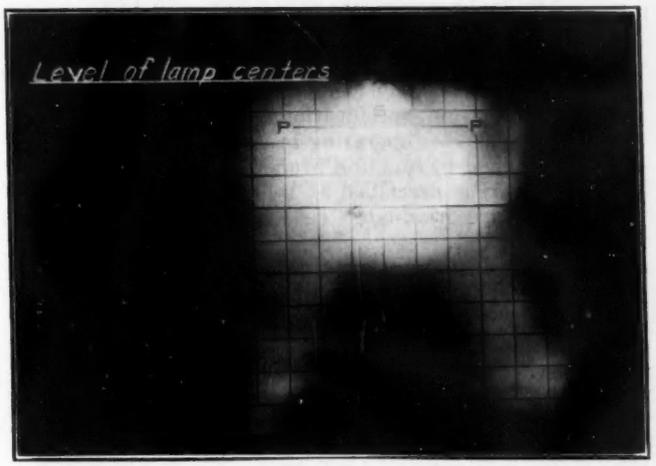

FIG. 7—BEAM FROM A BARE REFLECTOR OF THE TYPE SHOWN IN FIG. 5
This Illustration Was Reproduced from a Photograph of the Beam as It Appears on a White Screen 25 Ft. Ahead. The High Intensity Near the Top of the Beam Is Shown by the Practical Obliteration of the Letter B on the Screen

FIG. 8—AN ASSEMBLED HEAD-LAMP
A Lens Has Been Placed in Front of the Reflector Shown in Fig. 5 To Give the Beams the Required Lateral Spread

Specially Designed Reflector and Lens

A head-lighting device has been developed by the company with which I am associated which gives a beam distribution that amply complies with the Society's desirable-illumination specifications. The device consists of a special reflecter operating in conjunction with a lens that is designed to function properly with it. The principle employed is described as follows:

The standard head-lamp reflector is a paraboloid of revolution. It, therefore, has a focal point and should a point source of light be placed at this focal point, all rays of light intercepted by the reflector would be reflected parallel to the reflector axis. But commercial lamp-filaments are not point sources of light and, accordingly, the light emanating from the various sections of the filament is displaced from the focal point by varying amounts. The effect of this displacement is evidenced by the amount of divergence of the reflected rays. One will readily recall that when focusing ordinary head-lamps, by drawing the lamp filament behind the focal point, the reflected rays diverge as shown in Fig. 3. Likewise, when the lamp filament is moved ahead of the focal point, the reflected rays will cross as shown in Fig 4. From the viewpoint of light control and glare, it is necessary to eliminate all upwardly directed rays. In the two above-mentioned illustrations it would then be necessary to discard either the light coming from the upper half of the reflector in Fig. 3, or the lower half of the reflector in Fig. 4. Either method, of course, is extravagantly prohibitive. Conversely, however, if the lower half of Fig. 3 could be combined with the upper half of Fig. 4, all the light would then be reflected in a downward direction and none of the light would be wasted. This is exactly what is accomplished by making a reflector that has two focal points located on a common axis, but separated by a definite distance, and then placing the bulb filament between these foci as illustrated by Fig. 5.

It can be seen readily that the filament C is ahead of the focal point of the upper half U, which is a condition comparable to that in Fig. 4, while it is also behind the focal point of the lower half L as in Fig. 3. Thus, all rays are directed parallel to the reflector axis or in a downward direction. But, since the focal lengths of the two halves are different, the curvature of the upper half is different from the curvature of the lower half, and the two surfaces will not intersect nicely on the horizontal meridian to make one continuous surface. A continuous surface is evidently necessary. This is accomplished by joining the upper half with the lower half by two transition surfaces, T_1 and T_2 as shown in Fig. 6.

The cross-section of the beam from this reflector is semi-circular in shape. Fig. 7 is a photograph of the beam from the bare reflector as it appears on a white screen 25 ft. ahead. By close examination it can be seen that the B on the screen is practically obliterated, which is an indication of the extremely high intensity near the top of the beam. This is a characteristic of this type of reflector, which lends itself readily to good design possibilities for desirable illumination, and forms the foundation for the final light-distribution.

Now that the reflected beam has all of the light-rays controlled properly in the vertical angle and has the desired "hot-spot" at the top of the beam, it remains to design a lens that will select predetermined portions of the beam properly and give them a definite spread laterally until the desired beam pattern and smoothness of field is obtained. A photograph of a special lens assembled in a head-lamp is shown in Fig. 8. The beam from the bare reflector, as illustrated in Fig. 7, appears in Fig. 9 as modified by this lens. The high intensity still remains at the top of the beam. The screen on which the beam was thrown when photographed was not of sufficient width to show the complete spread at the bottom of the main portion of the beam.

Parabolic-Reflector Disadvantages

A large majority of head-lighting devices employ the standard parabolic reflector which throws a beam that is circular in cross-section. The circular beam is then spread laterally by flutes or ribs that are either molded in the lens or stamped in the reflector. Some means must then be employed to tilt the beam downward until the top is at the level of the lamp centers. This is accomplished by tilting the entire head-lamp or by placing horizontal prisms on the lens for deflecting the light

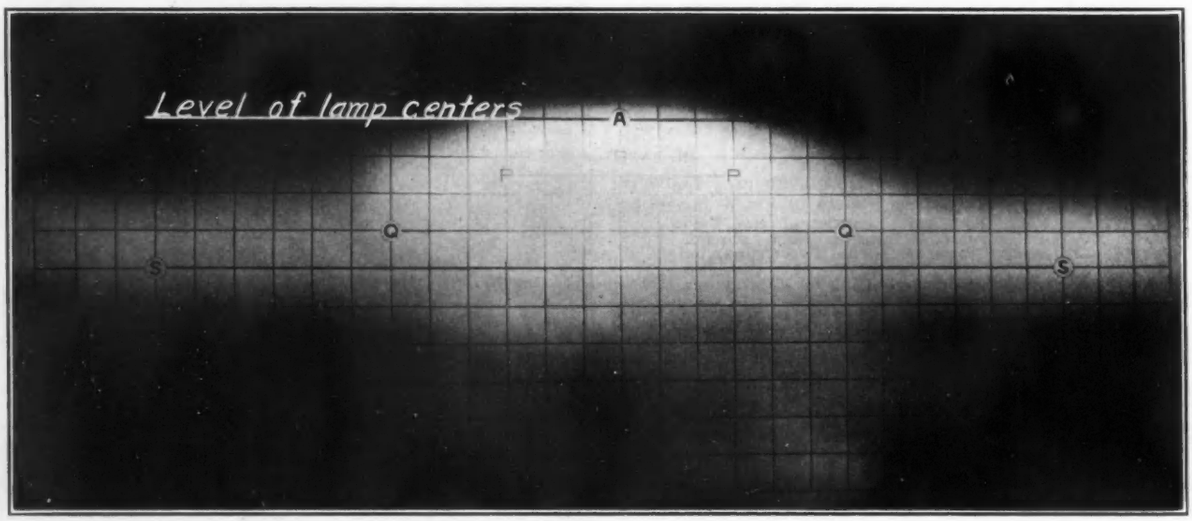

Fig. 9—Beam from the Assembled Head-Lamp Shown in Fig. 8

The Modification in the Beam from the Bare Reflector by the Addition of a Lens Can Be Seen by Comparing This Illustration With Fig. 7. The High Intensity Is Still at the Top but a Lateral Spread Is Given the Beam. The Screen on Which the Beam was Thrown when Photographed Was Not of Sufficient Width To Show the Complete Spread at the Bottom of the Main Portion of the Beam

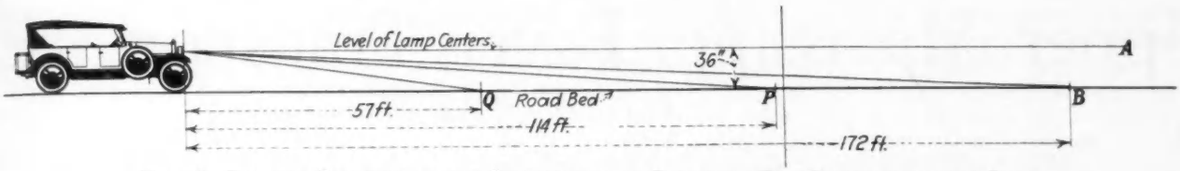

FIG. 10—RELATIVE LOCATION OF THE INTERSECTION OF DIFFERENT TEST-POINTS WITH THE ROAD
This Diagram Shows the Distances in Front of the Car at Which the Points *B*, *P* and *Q* in Figs. 1 and 2 Are Located with Head-Lamps 36 In. above the Roadbed

downward. Usually, in either case, the original vertical gradation of intensity remains unaltered and, since it is characteristic with such devices for the maximum intensity to be at the center of the beam as originally reflected, the maximum intensity or "hot-spot" is still at the center of the beam after it leaves the head-lamp.

When the maximum intensity is at the center of the beam, a brightly illuminated area appears on the roadbed about 80 to 90 ft. ahead of the car. Ahead of this area, the illumination on the roadbed diminishes rapidly inasmuch as the intensity in the upper part of the beam is less. While driving over strange roads at night, with a beam of this character, one unconsciously endeavors to look over and beyond the bright area in an attempt to secure greater vision. It is a natural characteristic of the eye, however, to follow the brightest area of the roadbed, with the result that the driver's vision automatically returns to the bright area instead of being fixed at a distance of several hundred feet. Added to the continued effort to see beyond the bright area, is the reflection of light from this highly illuminated area to the driver's eye, contrasting itself against the remainder of the field. Tests have shown that eye fatigue results when the eye is subjected to these conditions for any extended night-driving. Eye fatigue can, fortunately, be averted by subjecting the eye to conditions under which it normally functions during most of the time, namely, the daylight hours. When driving during the daytime the ideal roadbed illumination is attained, the illumination being smooth and uniform. From the driver's viewpoint, night driving would be a pleasure if daylight conditions were duplicated. The nearest that one can approach daylight road conditions and at the same time maintain a legal driving-light, is to produce a beam having a distribution that will illuminate the roadbed uniformly from the rear end of the beam on out several hundred feet ahead of the car.

Roadbed illumination is approximately inversely proportional to the square of the distance from a given point on the road to the head-lamps. By referring to Fig. 10 we find that, with the head-lamps 36 in. above the roadbed, points *Q*, *P* and *B* are 57, 114 and 172 ft. ahead of the car respectively. These distances bear the ratios of one, two and three. Then with a given intensity at *Q*, four times the intensity at *P* and nine times the intensity at *B* would be required to secure a uniform roadbed illumination. On this basis, assuming the minimum intensity recommended at *Q* by the Society of Automotive Engineers, which is 4000 cp., we should obtain 16,000 cp. at *P* and 36,000 cp. at *B*, if we are to expect the minimum of good uniform roadbed illumination

PHOTOMETRIC-TEST VALUES

In Table 3 are listed average authentic photometric test-values of the lens and reflector combination developed. By comparing these values with the data listed in Tables 1 and 2, it can be seen readily that they not only comply with the legal requirements, but amply exceed the Society's desirable-illumination specifications. When driving behind this beam, legally adjusted, the observer sees the roadbed uniformly covered with a blanket of light that gives him long-range vision which results in a feeling of security and comfort. One might expect at first thought that the exceedingly high intensity at the *B* point would produce an undesirable "hot-spot" in the distance. By working this out mathematically, however, it is apparent that the intensity at *P* is approximately four times the *Q*-point value and it is nine times at *B*, which, as stated above, is the correct ratio of intensities for uniform illumination.

TABLE 3—AVERAGE PHOTOMETRIC-TEST VALUES FOR THE REFLECTOR AND LENS DEVELOPED

Point	Intensity, Cp.
A	5,275
B	40,200
C	1,255
D	640
P_L	18,600
P_R	20,600
Q_L	4,275
Q_R	4,400
S_L	2,330
S_R	2,150

In this manner eye-strain, with the resulting fatigue, is reduced to the minimum and the increase in the range of vision is marked, which is a distinct advantage in sighting pedestrians, turns in the road, obstructions and the like. In addition, the bottom of the main portion of the beam is spread 5 deg. beyond the *S* point, which is a distinct advantage when turning sharply into a cross-road or into a driveway, and sufficient light is provided to be useful. The two transition surfaces throw two legs of light downward, the back ends of which strike the road so close to the car that the top of the radiator obscures them from view, so that no areas ahead of the car are unlighted. It is my opinion that the desirable-illumination specifications which the Society has adopted will lead the way to and act as an incentive for improved design in head-lighting equipment. There is no question regarding the unlimited field for improvement along head-lighting lines, for head-lighting eventually should develop to the extent that a car can be driven as comfortably, as safely and as fast over strange roads during the dark hours as during the daytime. But, as stated at the outset, this can be accomplished only by the combined effort and cooperation of all concerned. The development of desirable illumination is only one of the many problems involved.

Upper Mississippi River Transportation

By J. BRODIE[1]

MINNEAPOLIS SECTION PAPER *Illustrated with* DRAWING

FOR nearly a century the Mississippi River has been an important factor in transportation. Passenger steamers, carrying freight as well as passengers, made regular trips. Formerly the railroads distributed the goods brought by the steamboats and collected other products from the farms on the return trip. But the traffic became so great that the railroads, during the period of their greatest development, built lines paralleling the river in an effort to get the business, and it was not long before the river lines went out of existence.

During the war the Government, endeavoring to develop all available water facilities, built a fleet of 19 barges and 4 towboats, primarily for transporting ore and coal between St. Louis and St. Paul. These boats are now lying idle at St. Louis. Very little improvement has been made in the manner of navigating the river since the early days and the stern-wheel steamboat has always been the prevailing type of craft used. A few side-wheel boats served as packet boats but did little towing. The loading and the unloading were done by negroes. No effort was made to improve the terminal facilities and the safety and the protection of freight were not provided for, so that many shipments were destroyed by rain or were pilfered on the way. Shippers accustomed to the better service given by the railroads complained, and had it not been for the fact that shipments reached their destinations sooner by water than by rail the boat lines would have gone out of business sooner than they did. A boat used to make the round-trip between St. Paul and St. Louis in 10 days, whereas 2 weeks was required by rail.

Realizing that the public considers the Mississippi River to be a great economic factor, the Government annually spends large sums of money to keep the channel navigable. At the present time the channel between Minneapolis and St. Louis has a depth of 4 ft., and a depth of 8 ft. from St. Louis to the Gulf, but it is narrow and the barges and the towboats designed by the Government, although possessing many advantages, cannot navigate it without running aground.

The differing requirements of passenger and freight business make it advantageous that each kind should be handled separately. The short packet business, which used to be profitable, has been largely lost since the introduction of motor trucks, but although these vehicles are discouraging to the short-haul business of the waterways they are beneficial to the long-haul business. Extensive economies in transportation have been taken advantage of on nearly all inland waterways with the exception of the Upper Mississippi, but in this instance the Government and the people seem each to be waiting for the other to make the first move.

Since a demand for the development of water traffic on the Upper Mississippi exists, a suggestion is offered that a start should be made by building boats that meet the conditions as they are at present, those for carrying freight being given precedence. The size of the boats should depend on the quantity of freight available and should not be greater than that of the passenger boats now in service. Both the barge system and self-propelled boats have advantages; the proper type to be selected must depend on the dock facilities that are provided for loading and unloading. To meet existing requirements a compromise type has been considered.

On account of the shallow draft, the choice of the power to be used is important. Although the application of direct-connected steam engines to slow-moving propellers is the most simple system, the weight of the boiler, the engines and the fuel is so great that little space remains for cargo. The internal-combustion engine overcomes this difficulty, but the shallow depth of the channel is again an obstacle. Efficiency would require that the propellers on slow-moving boats should be greater than the depth of the channel will allow. The tunnel type of boat is said to meet the conditions but it also encounters difficulties in that its power to back with a strong sidewise force is not pronounced, there is danger of fouling the propeller in shallow water and the moving parts wear out on account of the sand drawn in from the bottom of the river. On the whole, the stern-wheel boat seems to be the most suitable, if the speed of the internal-combustion engine is sufficiently reduced.

When cranes and other mechanical devices are available for handling the freight, boats having hatches at the top are in demand. The freight is then moved by slings that remain about the freight until it reaches its destination. Containers also are frequently used. But the dearth of equipment of this kind at present on the Upper Mississippi makes it necessary to meet the handling problem by equipping each boat with a small hoisting engine, designed either to work with a derrick or to drag hand-trucks up or down a gang-plank. This self-contained and flexible arrangement makes it possible to handle freight under the widely varying conditions at different points on the river.

TRANSPORTATION on the Mississippi River from St. Louis to the head of navigation is a subject upon which we have very little information in the way of direct data. The upper stretch of the river has had so little actual use in the last few years that no data are available on which to base an analysis. All that can be done on the matter is to make deductions from the experience gained through the use of other waterways that have been employed in carrying on uptodate transportation.

Formerly the Mississippi River between St. Paul and the Gulf of Mexico was an important factor in transportation. It was just 100 years ago on May 10 of this year that the first steamboat landed at Fort Snelling. Between that time and 1918 the river was in constant use for transportation. In the early days, logs were assembled into great rafts and floated down the river to the different saw mills. This logging traffic was of large proportions and a great many steamboats were used in the service of towing. With the logs going down and quantities of settlers' supplies, such as mules and farm implements, coming up, and with the constant utilization of the river for freight transportation, it was natural that many people were attracted to the river business. There was so much traffic on the river that its economy was always in mind and there was a natural flow of commerce because of the habit of using

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the water route. Steamers, carrying freight as well as passengers, plied up and down the river on regular trips. Many settlers have come to the Northwest on river boats and often these settlers came on the same boat that carried the equipment with which they started their settlements.

Reaching into the inland territories, railroad builders made their way and distributed the goods that the steamboats brought up the river. As the railroads brought back the products of the farms, the traffic soon became so heavy that it was worth the while of the railroads to build lines paralleling the river and to make an effort to get the business.

Decline of Water Transportation

This was the period of railroad development. The people of the country saw the great advantages of having their rich country literally covered with rail transportation lines, and the power attained by the great railroad builders was almost absolute. The railroad builders naturally were men of high ambition. Industry was absolutely under the control of the railroads because its whole existence was dependent on rail facilities. It was not difficult for the great rail builders to subdue the competing boat lines and traffic on the river was gradually put out of existence.

After the well-known Diamond Joe line died out, the Streckful line continued in the river business for a number of years. It ran regular packet boats between St. Louis and St. Paul and carried on a fairly good freight and passenger business as late as 1918. Since that time there has been practically no business at all on the river except a little excursion traffic. The Streckful line is still running some fine excursion boats out of St. Louis. In St. Paul, Captain Newcomb, who owns and operates the steamer Red Wing and the barge Manitou, has maintained a good excursion business until the present time.

In the summer of 1922, the River Transit Co. put into operation a small steel barge for freight business between La Crosse, Wis., and Minneapolis. I believe this is the only attempt to carry on freight business on the upper stretch of the river in a manner similar to that successfully carried on on other inland waterways. It is certain that this is the only attempt ever made to operate a regular boat to the city of Minneapolis. It is generally accepted that this attempt, although carried out in a small way, has proved very successful.

During the war, the Government endeavored to bring water facilities up to capacity and to a suitable standard and a large fleet of barges and towboats was built for use on the upper river. Some of these boats, the finest specimens of craft ever built for shallow water use, were constructed at Stillwater, Minn., by the Minneapolis Steel & Machinery Co. or its associated interests. This fleet consisted of 19 great barges and 4 towboats. It was originally intended for transporting iron ore from St. Paul to St. Louis and coal from St. Louis to St. Paul. This plan has not yet been carried out. No facilities have been developed at the terminals to handle the cargoes that these boats can carry and there can never be traffic in these commodities without adequate handling facilities. These boats are lying idle at St. Louis now and their idleness has greatly discouraged the people of the district in their hopes and aspirations for the cheaper freight rates that would be possible by using the natural waterway flowing by their doors.

There has been an almost complete absence of development or improvement in the commercial utilization of the upper river in 50 years. The towing of large rafts of logs brought out the great advantages of the common stern-wheel steamboat. This type of boat makes it possible to hook up behind a large tow, the steering advantages being such that the tow may be swung round, stopped and started in a very remarkable manner, which makes it possible to navigate the crooked and impeded channel of this end of the Mississippi. The ability to back with a strong sidewise force has made the stern-wheel steamboat the universal type for towing.

Numerous side-wheel steamboats, plied the river in the olden days, and still do so, but these were almost always used as packet boats and did very little towing. Such a boat has the advantage of being able to twist itself round within its own length but lacks the strong sidewise force necessary for maneuvering a large tow on the river.

Up to the year 1918 freight was handled entirely by negroes from the South. These men were cheap to hire and required little in the way of accommodations. They slept on the boats, in or about the freight, and on the decks; their food was not of the expensive variety now required by labor. An ample supply of this labor was available so that the boat lines did not suffer from want of it. All freight was carried into and out of the boats on the backs of these negroes, no modern methods of handling being ever attempted.

No improvement was made in the safe-keeping and the protecting of freight. The freight itself was stowed on the decks of the steamboats and its protection was more or less doubtful. Many shipments were destroyed when a driving rain swept in on the cargo. Other shipments were pilfered by the crew that made its quarters between the boxes and bags. Shippers accustomed to the better service given by the railroads with their adequate freight depots and well closed-in freight cars complained. Freight insurance was high and but for the fact that shipments usually reached their destinations in less time than by the rail carriers and that the rates were lower, the boat lines would have gone out of the freight business much sooner than they did.

Public sentiment has insisted that the Mississippi River is a great economic factor in transportation, and the government has done a large amount of work on the channel to keep it navigable. Thousands of wing dams have been built to confine and guide the flow so that a deep channel will continually be washed out. Sand bars are continually being dredged out. A great dam has been constructed at Keokuk, Iowa, where a portion of the river used to be almost inaccessible. Now a lock is located there and all kinds of river craft are taken through without the slightest difficulty. The rapids above Moline, Ill., are being subdued by Government engineers, and at Minneapolis a dam makes Minneapolis accessible by river boats. This dam was not put into use for regular commercial purposes until the summer of 1922, when the River Transit Co. ran a regular freight barge between Minneapolis and La Crosse, Wis.

A boat used to make a round-trip from St. Paul to St. Louis in 10 days; by railroad it takes 2 weeks. Freight delivered to the boat would reach the terminal at the other end within 3 or 4 days, making a quicker transfer than could be made by the railroad. A customer recently inquired when we could haul some goods to New Orleans for him; he wanted very much that we take the goods to New Orleans because he said he was sending them to Baltimore to be shipped to Tacoma through the Panama Canal. This shows that a demand for facilities to reach the ocean from Minneapolis exists.

At the present time the channel of the Mississippi River has a depth of 4 ft. all the way from Minneapolis to St. Louis; from St. Louis to the Gulf it has a depth of 8 ft.

Each spring as soon as the ice is out of the river, the Government sets out buoys to mark the channel for navigators. The marks on the shore, together with this system of floating marks, make it possible for even an inexperienced person to steer a fair-sized boat up and down the river without difficulty.

What River Freight-Transportation Requires

Considering the present condition of the channel and the care demanded by shippers for their shipments, certain requirements must obtain in the design of freight-carrying boats such as

(1) The maneuvering ability of the stern-wheel steamboat of the old type is primarily essential for moving any kind of load on the river. Whether it is necessary actually to have a stern-wheel steamboat to get this maneuverability will be discussed later

(2) Adequate protection for the cargo under all kinds of weather conditions is absolutely essential, because of competition with carriers that furnish the very best of protection. Reasonable speed and continual running also are required for the prompt delivery of shipments

(3) Cheap and dependable methods of loading and unloading freight. Great stress should be laid on the handling methods, because river shipments will always be in competition with rail freight, and the method of handling must be of such character that the freight will not be damaged

(4) The boats must be operated with such frequency that the sailing dates will be close enough to make the proposition attractive to the shipper in the way of early delivery. With either a small traffic in merchandise or a heavy traffic in commodities this frequency of sailing must be maintained; the first, to satisfy the shipper, the second, to keep the terminal equipment active for handling the shipments

The fleet of barges and towboats that the government built was designed to handle heavy commodities. The barges have a capacity of about 1600 tons each and the towboats, equipped with about 2000 hp., are capable of moving three or four of these barges at one time. The design of such a fleet has many advantages. In the first place, the towboats, which are of the stern-wheel type although very much improved over the older type of boat, are such that the largest tows can be so handled that it is possible to operate wherever there is a path wide enough. The large capacity of the barges makes it possible to take loads that, per ton, can be transported cheaply. The barges are of the open type, which makes loading and unloading at properly equipped terminals very cheap. Except for the fact that the channel is too narrow and too crooked to steer one of these tows in, without its running aground, the advantages are logical and practical. We have been informed that the cost to the Government for this fleet was approximately $3,500,000; it is too bad that this money could not have been spent for something that would have done more toward creating river-borne commerce.

Cheapness in handling freight is one of the prime requisites of any modern transportation method. One of the requisites in handling passengers is that the boats shall maintain definite schedules; another is that they shall not keep passengers waiting at the landings. These two requisites are not consistent. A water carrier cannot tell just how long it will take to load or unload a boat at a certain place, so time allowances must be made. If a load must be handled twice as fast as the most efficient rate, the expense goes up rapidly. Handling freight and passengers together must meet the requirements of the passenger service or the passenger service will suffer. Furthermore, stops along the route for handling freight are not attractive to passengers and the service will suffer from them in spite of the fact that much money may be made by taking advantage of local points because of the freight that is available there. By handling passengers on a passenger boat and freight on a freight boat, as is done by the railroads and by nearly all modern establishments, whether on land or water, these difficulties would be avoided.

Formerly the short packet service was profitable, but because of the improvement of the motor truck, good roads and the numerous passenger automobiles, this business on the river has not a very bright future. In contrast to this, the long haul by water is enhanced by the very elements that discourage short-haul business. With good roads and improved motor-trucks freight is put on trucks before being taken to the railroads. From a truck, the freight may be put on a landing just as cheaply as it can be put into a depot or on a car. Farmers who live 40 miles from a river town can take their products to the river town as easily as to a railroad town and can have the advantage of cheaper transportation to the market where the product must eventually land. This applies especially to cases in which the product is destined for ocean ports or for cities that are accessible to the river or to its navigable tributaries. Motor trucks and good roads, although discouraging to short water-hauls, are advantageous to the longer water-hauls. Using inland waterways for the cheap transportation of freight is becoming more and more common in the United States; we are beginning to appreciate the economics practiced in some of the other countries of the world and are now using constantly some of the natural waterways of the country in addition to many that have had to be made. Outstanding among the former is the Mississippi River below St. Louis where the government has built up a very extensive traffic with the line known as the Mississippi-Warrior Service.

Demand for Water Transportation of Freight

Herman Mueller of the St. Paul Association has described the conditions relative to the upper Mississippi River thus:

> The opening of the Panama Canal has brought about a great change in our industrial situation by reason of the cheap water transportation now available between the Atlantic and Pacific coasts. This, coupled with the necessary high level of rail freight-rates, makes it practically impossible for manufacturers in the interior to market their products in the Pacific Coast States; and the disadvantages under which they are laboring, as I see them, can only be overcome or equalized by providing water transportation on the Mississippi River to the Gulf of Mexico.

That river transportation can be carried on profitably and satisfactorily to the shipping public, provided modern facilities are utilized, is being demonstrated on the lower Mississippi and also on the Ohio River where the Jones & Laughlin Steel Co. operates boats and barges to move large quantities of steel products from Pittsburgh.

Wherever inland waterways are available in the United States, except on the upper Mississippi River, extensive

economies have been taken advantage of. The results have not shown that the additional prosperity brought about has increased the total business. The status of affairs concerning the relation of the government to the development of the channel on the upper river is expressed in another communication addressed to the late Senator Knute Nelson:

> As I view it, the situation in a nutshell has been just this. The Government has taken the position that appropriations for river work are needless because the river is not being used, and the people have taken the position that it is useless to attempt transportation on the river until the Government has made it possible to operate economically and efficiently; and I do not hesitate to say that in my opinion the Government should lead off.

The Twin Cities are virtually in a pocket. Our principal competitors are Duluth, Chicago and St. Louis, and they are improving their advantages more and more by using water transportation. The history of the world shows that no great industrial center ever has been developed that was not located on a navigable waterway. In my opinion, the Twin Cities are ideally located, because this is the logical point for the interchange of traffic with the rail lines, so far as the Mississippi River is concerned.

It is evident that there is a demand for the development of water traffic on the river. The question as to the methods by which such traffic can best be built is the one we must answer. Even if the river is not now in condition for the greatest economy, I am firmly convinced that its condition is such that some very extensive economies may be practised in transporting freight. It is evident that the more it is used, the more the Government will improve it and the more the cities will build terminal facilities. The problem of starting freight service on the river as it now is should be worked out.

Type of Boat Required

First of all, boats for carrying freight must be built. Such boats must be small enough so that they can be operated in the channel as it now is. The excursion steamers now in use have enough difficulty in following the channel during low-water periods and I think that no boat larger than they should be put on the river until further improvements in the channel have been made. These steamers are about 300 ft. long. The channel is maintained with a 4-ft. depth; to pass in such water at a reasonable speed without hindrance the draft of the boats should not be more than 3 ft. I feel sure that the most efficient freight-carriers for the upper river will be about 300 ft. long and 80 to 100 ft. wide, whether they be composed of tows, barges or single units.

One very important consideration in determining the size of craft to be put into use on the river is the freight that will be available at a single sailing. No doubt there is plenty of freight to be moved by the river route but it must be remembered that such freight as is available is now being taken care of in other ways. The business must be developed until the shippers get the habit of using the river route; and all shippers are not ready to try out a new service. If the most efficient craft for carrying freight is put on the river at the start, the amount of freight that the carrier can get will not be enough to make it possible to get the efficiency out of the craft.

Regarding the most efficient design for river equipment, there is some question as to whether the self-propelled boat or the towboat with barges is the more

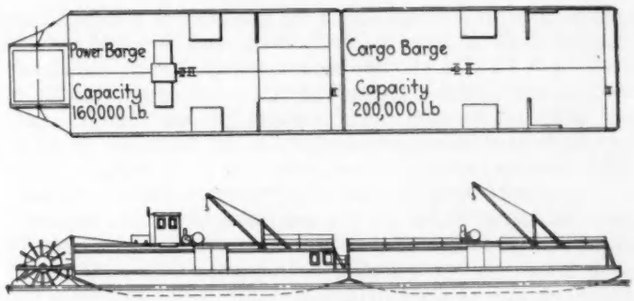

Fig. 1—Freight Equipment That Is Adapted to Present Conditions on the Upper Mississippi River

The Combination of a Power Barge with a Cargo Barge in Tow Is 128 Ft. Long and Has a Total Capacity of 360,000 Lb. with a 3-Ft. Draft. Both Barges Have a Structural Steel Frame with a Steel Plate Hull and a Sheet Steel Upper Structure and Deck. An Oil-Burning Internal-Combustion Engine Supplies Power to the Stern Wheel That Is Adjustable To Control the Dip

adaptable. The barge system is being used more and more on inland waterways and has great advantages in being very flexible. Barges may be left at docks for loading and unloading while the machinery for moving them is constantly kept busy. With the most efficient engines the capital invested is an important item, and to derive the maximum efficiency and make profits it is necessary that expensive power units be kept under constant load. With the barge system, a single crew, expert in moving barges with an efficient towboat, can move much more freight than with any other method. Loading and unloading cargoes become a special undertaking because barges are left at the docks by the towboat and a crew separate from the crew of the boat takes over the work of handling the cargo. On the New York State Barge Canal and on the lower river the barge system is being utilized almost exclusively.

The self-propelled boat has the advantage of being able to move as soon as the load has been put on or taken off. By putting into service a fleet of self-propelled boats, the most frequent sailings can be made with the least outlay of capital, and this feature alone is sufficient in some cases to demand the use of this method. Larger units, also, can be operated in the more confined channels. The disadvantages of this type are that the navigating crew and the engines are idle while the boat is at the dock.

In determining the proper type of boat to be used one must consider carefully the facilities for handling the cargoes. When dock facilities with cranes of large capacity and other mechanical appliances for rapid loading and unloading are provided, the time wasted at the docks is not so great as it is when the handling is slower.

To meet the requirements, the River Transit Co. has made what might be termed a compromise between the advantages of both the barge system and the self-propelled boat shown in Fig. 1. This system consists of a power barge pushing a cargo barge in front of it, the combined capacity of the two barges being 360,000 lb. when drawing 3 ft. of water. The cargo barge is of the ordinary plain square construction with a structural steel frame and steel plate hull and a sheet steel upper structure including the deck. Freight handling equipment of improved design that is adaptable to varied conditions at landings is provided. The power barge is of the same general construction as the cargo vessel. An internal-combustion engine using oil as fuel and controlled from the pilot house delivers power through a jack shaft and a chain drive to the stern wheel which is adjustable to control the dip. The engine room is located aft and the quarters for the crew are forward, both being sepa-

rated from the cargo space by partitions. Each of the barges is 64 ft. long by 28 ft. wide and the depth of the hull is 5 ft. It should be remembered that the boats shown are for the purpose of carrying merchandise of all descriptions and not for handling the heavier commodities that do not require protection from the weather. With the largest equipment operable in an efficient manner on the river under the existing conditions, it is likely that 300 or 400 hp. is the maximum that can be used; the class of power that is the most adaptable is open to argument. In considering this matter, the methods of applying the power to the water for propulsion is a decided factor.

With either the stern-wheel or the side-wheel boat, the slow motion of the propelling wheels makes the application of direct-connected steam engines by far the most simple. The weight of the boilers, the engines and the fuel in a boat that necessarily must be of extremely shallow draft is such that very little additional load can be carried. Many of the old types of steamboat have a draft of 4 or 5 ft. without freight loads. Then the question of fueling must be considered. If coal is used, either the boat must overburden itself with its own fuel or must stop at landings and take on fuel. The solution of this problem is, naturally, the use of oil.

Use of the Internal-Combustion Engine

Because of the small amount of power required on each unit, oil-burning internal-combustion engines of the present day are very adaptable. A minimum amount of labor is necessary to operate these engines and a quantity of fuel sufficient for a long trip may be carried without overburdening the capacity of the boat, so that freight can compose the largest part of the cargo. In the smaller units, the possibility of one man operating both the steering mechanism and the engine is a feature that cannot be overlooked. The efficiency of internal-combustion engines is so high that that particular phase of the subject goes without argument.

When the water is of sufficient depth, the direct-driven propeller-wheel is the most simple and practical when used with internal-combustion engines, as it requires only direct transmission and makes a light and compact arrangement. When used in very shallow water, a number of considerations demand attention. In the first place, to work efficiently a propeller must have a sufficiently free passage for the water to be acted on. The wheel must be of such size that its efficiency can be obtained. On slow-moving boats a great efficiency of the propeller cannot be attained with a very high rate of revolution. These factors limit the size of a propeller wheel; if 50 to 100 hp. is to be applied, the wheel would be greater in diameter than the present depth of the channel would allow. To overcome this difficulty, the tunnel type of boat is being used more and more and, it is claimed, actually furnishes the advantages required by the conditions. Some problems, however, seem to present real difficulties. One of the necessities of a towboat is the power to back with a strong sidewise force, and this quality is not very pronounced in a tunnel boat. Then there is always the chance of fouling the propeller in shallow water and the accessibility of a propeller wheel placed under the boat in a tunnel is not so easily worked out as is that of other forms of power application. The facts that in shallow water the propeller of a tunnel boat will draw a large quantity of sand from the bottom and that the moving parts under water will wear out are very pronounced and seem to have been a bugbear to many builders of boats of this design.

Efforts to solve the problem of drive on river towboats have pointed to only two types, the tunnel and the stern-wheel. Little objection can be made to the stern-wheel boat except that the speed of revolution of the internal-combustion engine must be reduced when applied to the wheel, and that the weight of the wheel and its supporting structure is excessive. It is generally agreed that no other type of drive can deliver the same effectiveness in steering and stopping as can the stern-wheel with rudders both in front of and behind it. Applying the power from internal-combustion engines is a comparatively simple engineering problem.

As in the long-haul truck business speed is a factor that brings profits, so on the river, too, speed is important. The happy medium in speed for boats must be attained. In transporting freight on the ocean and on the Great Lakes, an average of 10 m.p.h. is generally practised with the most uptodate equipment; on the river, the depth of the water limits the speed of the boats more than does deep-water travel. To drive a boat at the rate of 10 m.p.h. over a shoal with a depth of 4 ft. is almost impossible. If enough power were applied to drive a river boat at this speed, the water would be drawn from under the boat so that the boat would be sucked down on the bottom and forward progress would be almost stopped. I have often seen the condition in which cutting down on the throttle actually has resulted in increasing the speed of the boat. An 8 m.p.h. speed is about as fast as can be attained efficiently during low-water periods on the river, and more power than is necessary to give this speed will be largely wasted. By an 8 m.p.h. speed is meant 8 m.p.h. in still water. This will give about 5 m.p.h. up-stream and from 10 to 11 m.p.h. down-stream.

Freight Handling and Protection

Besides the necessity for considering the type of boat that can be handled most expediently on the river, the means for protecting the freight and for easily loading and unloading it require attention. When efficient mechanical devices are provided at the landings, the boats having hatches in the top have proved to be very much in demand. The barges in use on the lower river are provided with hatches so that the cranes can reach any part of the boat without the need of moving the freight horizontally. Freight is lowered into the hatches in slings that are left around it until the barge is brought alongside another crane at the other end of the route. Here the crane hook is attached to the sling and the freight is lifted out of the barge and placed in the warehouse or a car on the landing.

In some instances freight is handled in containers, that is, large cases made so that the freight packed in them is protected from the weather, no matter whether it is transported in open or in closed barges. These containers make loading or unloading a quick and easy task when power is available to lift them out. This system has recently been put into practice on the New York Central Lines between New York City and Buffalo, and I am informed that it is proving a great saving to both the shipper and the railroad. On the New York Central Lines the containers have a cubical capacity of 438 cu. ft. and a weight capacity of 7000 lb. Special container cars are used, and cranes at the depots transfer the containers from the cars to trucks or drays by power derricks. Such a system will no doubt be used more extensively by both the rail and the water carriers because of the economies to be gained, but a system that shippers will be able to avail themselves of advantageously requires

time to build up. It has been suggested that freight might be handled efficiently on the river by using motor-truck trailers that could be loaded on a barge with tractors and thus effect a saving in the handling cost. This method would no doubt reduce the handling cost but the amount of capital that would be tied up in the rolling equipment and the additional weight that would have to be transported would more than offset the saving in handling over a system of containers.

At present practically no power equipment is available at points on the upper river. The problem resolves itself into providing these facilities or providing each boat with means for doing its own loading and unloading. On the equipment planned by the River Transit Co. each boat will be equipped with a small hoisting-engine, which can be used either for hoisting in a derrick or for pulling hand trucks with a drag-line up or down a gang-plank. This arrangement will make it possible to handle freight under the widely differing conditions met with at the river points. Taking everything into consideration, the equipment that will be operated first on the river must be self-contained and flexible because the exacting and divergent demands of a new business must be fulfilled.

THE DISCUSSION

A. F. MOYER:—Will Mr. Brodie explain a little more completely the manner of transmitting power from the engine to the paddle-wheels and also what difficulties may be encountered in reversing large heavy paddle-wheels?

J. BRODIE:—That is a simple engineering problem. We intend to reverse the paddle-wheels by using a tractor transmission with a drag-brake. We shall throw the engine out of engagement with the transmission, drag the brake until the paddle-wheel stops and then engage the clutch in the reverse direction.

MR. MOYER:—I once designed an outfit of this kind. We used a 75-hp. engine, running at 600 r.p.m. and drove to a countershaft with a bevel gear and from there to the wheel with chains. A conventional marine reverse-gear of the planetary type, revolving as a solid unit for forward drive and engaging a brake-band on the outside of the drum for the reverse was employed. That brake-band, originally of metal, was bored out and lined with asbestos, but even then sparks of fire were thrown off when bringing the large heavy paddle-wheel into reverse motion. We also used a large powerful brake on the countershaft for bringing the paddle-wheel to rest before reversing.

CHAIRMAN A. H. BATES:—What will be the size of the power unit in this particular barge?

MR. BRODIE:—We are figuring on a 75-hp. engine.

MR. MOYER:—Is the trucking of freight done entirely by the shipper?

MR. BRODIE:—Only when the shipper is accustomed to ship in less-than-carload lots, in which case he takes the merchandise to and from the depot at his own expense. That is the case also with carloads when the shipper has no side-track. Almost every shipment is taken from a side-track and the shipper bears the expense of putting the goods into the car, but the car is put right at his door. To meet this competition the boat line absorbs the trucking on carload lots. The boat line fixes the price of transportation to and from the docks for all the smaller shipments.

WHEAT PRODUCTION

IT cannot be too plainly stated or too often repeated that the United States is now a relatively small factor in making world wheat prices. Canada is a much larger factor and European markets are receiving large quantities of wheat at lower prices than even Canada is making. Moreover, Canada and other countries are able to produce wheat at lower costs than those ruling in this Country.

As a general proposition, the farmers of this Country should reduce their production of wheat. Other crops will pay better. This statement applies wherever wheat has been the principal crop until soil deterioration has taken place. It follows by the logic of the situation that no plan which will have the effect of maintaining the production of wheat for export will solve the existing problem.

The state of prosperity in the industrial sections which is contrasted with conditions in the agricultural sections is due to activity in construction work, artificially restricted during the war; and the high wages are supported by high rents and other factors in the cost of living arising from the war. Not until industry itself is in equilibrium will prices be equalized.

Excepting a few months in the early part of 1923 copper has been selling ever since the war below the average prices of 1913, and is selling below it today. Many copper companies are either shut-down or producing at a loss at the present time.

Wages are the principal factor in the unbalanced situation. Wage-earners in the highly organized trades have resisted reductions from the wages established when prices were at the high level, and where moderate reductions were effected have demanded and obtained restorations in whole or in part. The increased price of woolen clothing is partly in the price paid the wool-grower for the fleece and the rest in wages paid for labor in making the cloth and the clothing. The increased charges of the railroads are all accounted for in higher wages to railroad employes, coal miners and workers who make the various supplies entering into the cost of railroad service. If everything goes up in price to correspond with the rise of wages, the wage-earners will lose all their gains. Farm implements are better and cheaper here than elsewhere. Automobiles are cheaper here than elsewhere.

That diversified farming will rapidly take the place of one-crop farming in the Dakotas is the assurance given by everyone who is familiar with conditions in those States. Indeed, the change is already well under way. Wheat always has been the favorite crop of the pioneer in a new country. It was the chief crop of western New York when that was a new country and when the milling industry was established at the falls of the Genesee River. It was the chief crop in the early years of every State from New York and Pennsylvania westward to the plains. Everywhere, as the farmers became forehanded and able to become stock-growers, wheat gradually was reduced to a subordinate position and either took its place in a crop rotation or was dropped entirely, as with most farmers in Iowa. North Dakota soil and climate produced wonderful wheat crops in the early years there but, as the natural result of drawing continually on the same soil constituents, the crops have become uncertain and the grain is not up to its old-time quality. For the 5 years ended with 1922, the wheat crop of New York State averaged approximately 20.0 bu. to the acre, while that of North Dakota was only 10.4 bu. to the acre. That is abusing a State's resources. The soil of North Dakota is not exhausted by any means, but it is sick of the treatment it has received.—National City Bank.

The Relation of the Vehicle Builder to Motor Transport

By DAVID BEECROFT[1]

MID-WEST SECTION PAPER

MOTOR trucks, motor cars and motorbuses used wholly for business purposes are considered by the author in his plea for more clearly defined relations between the producer and the consumer. The paper is largely a presentation of the view the engineer must take of the situation. The dollar-earning fundamental is the reason for the author's consideration of the subject. Lack of close relations between the producer and the consumer was caused by (*a*) the influence of the system of sales through the distributor and dealer plan of organization and (*b*) the lack of a keen realization that motor trucks can be well sold only if sold by virtue of their dollar-earning capacity. A third influence was that of the war, with its unexpected demand for vehicles.

Detailing the part the engineer should play in obtaining the closer relations mentioned, the paper treats different phases of the problem under headings of what the engineer has not done, major engineering conditions, maintenance aspects, cost accounting and fleet operation, motor-vehicle delivery-systems, separate transportation departments, privately owned service-stations and arguments favoring them, possible economies and future equipment.

BETWEEN the producer and the consumer of commercial motor-vehicles a set of relationships exists which must be considered carefully if the greatest measure of success is to come to both for a given expenditure of effort and money. In applying this thought to the field of motor transport, I have in mind only transportation in which motor trucks, motorbuses and motor cars are used exclusively for business purposes. The motor truck and the motorbus are just as completely dollar-earners for their owners as the printing-press is for the publisher, the steam-shovel for the building constructor, the locomotive or the Pullman car for the railroad, or the multiple-spindle drilling-machine for the factory.

This paper is largely a presentation of the view the engineer must take of the situation. We are all creatures of tradition, and it is natural that the engineer who has spent a good portion of his time in the non-business automobile field should carry with him many of the viewpoints he acquired therein when he enters the truck field.

The dollar-earning fundamental in the truck or bus is the only reason for a consideration of this subject. It is this cardinal consideration that not only invites but makes imperative closer relations between the manufacturer and the consumer. That both the builder of commercial motor-vehicles and the user of them have had problems to cope with in the past few years has been so apparent that comment in the connection is scarcely necessary, except as it serves to focus attention on the fact that closer relations between the two parties in the past might have improved the condition of both materially. The condition of the industry in the last 3 years lends emphasis to this observation.

Two major causes contributed to the lack of as close relations between the maker and the consumer as was desirable. First came the influence of the system of automobile sales through the distributor and dealer plan of organization. This plan was followed too literally by not a few motor-truck merchandisers, keeping the builder and the consumer apart except as the former found it necessary to send his special sales representatives to assist the dealer in executing the sale. Where branch-house organization was relied upon, a much closer contact between the two parties resulted. Second, came the lack of keen realization that motor trucks can be well sold only if sold by virtue of their dollar-earning capacity. The automobile may be sold by virtue of the smoothness and the power of its engine, its body design or its interior finish, but its performance rarely is measured with the yardstick of earning capacity as in the case of the truck and the motorbus.

To these two reasons for lack of close relations between the manufacturer and the consumer might be added a third contributing factor, namely, the influence of the war with its unexpected demand for vehicles due to the stimulation of industry and also to the assistance the railroads required. This influence permeated not only the manufacturing centers but reached into every State of the Union and into every industry. It was only in June, 1920, when the deflation movement of our banking system was started, that a realization of what had taken place under war influences began to be appreciated. The day for taking inventory had arrived. Since 1920, our manufacturers have had three fairly lean years in which to study the errors of yesterday, and our consumers have had three hectic years in which they have been endeavoring to put their motor-transport departments in order following the confusion and derangement of war days.

Thus we can make a fairly long-distance survey of these manufacturer-consumer relationships at this time, and so have pass before us the sins of omission as well as those of commission; for it can be said truly, if I may paraphrase a thought from Holy Writ, that we have in motor transport left undone many of the important things we should have done, and we have done many of the foolish things we should not have done. There has been a lack of perception of how the maker and the consumer should travel side-by-side and step-by-step in shaping the motor-transport industry during these, its formative, days.

THE ENGINEER'S PART

In considering the part the engineer should play, we will think of him as the representative of the manufacturer, because he has been responsible for the design of the vehicle that has been sold into the dollar-earning zone of the user. Along with the engineer must be considered the sales organization. As in any new industry, while pioneering work was being done by the engineer, the user was also doing pioneering work in his field. The builder sold an imperfect vehicle, a development from automobile design in most instances; and the user started

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operating the vehicle as a substitute for the horses it displaced, with little thought of anything else, as he did not appreciate the possibilities that lay in the vehicle. He failed to recognize its ability to extend the borders of his business world, he failed to see in it the beginning not merely of a new medium of transportation but a very potential instrument for the expansion of his business. The evolution of this thought might be traced through the last 10 to 15 years, but we must bridge that period and meet face-to-face the condition as it exists today, as it has existed for the last 2 years, and as it may exist in the next year or more.

In the field of motor transport, we feel that the big contest among builders for positions in the industry lies ahead. There is a crystallization taking place today that augurs well. There has been a vast amount of liquidation, but there has been much more in the automobile field. There is a clearer defining of the field. Many companies that have attempted to be national distributors have recognized the folly of this and have picked out local areas for themselves. Many other companies have taken up the work of specific uses. But factors that have entered the industry in the last year or so indicate that the next 3 or 4 years at least will disclose much more definitely the companies that will continue and the respective fields in which they will remain.

Most of the consumers are purchasing transportation today rather than buying specifications. In any new industry there always will be a gradually diminishing percentage that will buy specifications rather than transportation. There was a great amount of buying of specifications during the war, purchasing wherever it was possible to purchase, and there has been considerable of it since; but it is encouraging that a great many users realize that this is one of the poorest methods of purchasing.

What the Engineer Has Not Done

What has the engineer not done that he should have done in cooperation with the consumer in this field of motor transportation? The answer is one of analysis. First, consider the motor truck. The truck user or fleet owner has a transportation problem. Formerly, he built his entire system of transportation around the horse. The boundaries of his business zone were determined by the mileage capacity of the animal. The shipping-room facilities were planned in accordance with the horse's pace and haulage capacity. The horse was the key. Then came the motor truck. There was no reason why the engineer and the builder should not have gone into the field, studied the transport needs of the user at first-hand and scientifically applied the vehicle to the work. A few of them did.

Work of this character was started in 1911, but it was done largely by the sales-engineering department. This work was not so general as it should have been. It is unfortunate that the engineer did not take a greater part in it. Excellent work was done by leading factories in sales engineering, but the engineer's ability to analyze and design in response to analysis was not availed of adequately. Here is where the great opportunity for the engineer still exists. Our engineering has not reflected completely the knowledge possessed by many companies. Excellent scientific applications were made. A great volume of facts was collected, but too often the data reached the proverbial pigeon-hole and remained there.

Major Engineering Conditions

There are two major considerations to which I invite the attention of engineers. The present design of vehicle must be modified greatly to meet the change in the times. The need is for an engine designed to meet the needs of the user and, at the same time, give greater horsepower per unit of piston displacement than that we have today; an engine whose life will exceed very materially that of those now on the market. The same thing may be said with regard to other units. For engineers, the work lies ahead. Design what might be named a maintenance engine as well as a power engine or a factory-production engine. Get the owner's viewpoint. Wear his shoes for a few weeks or months of each year. Look at the job through his glasses for a 12-month period. Stop designing engines and vehicles for yourself; design them for the man who uses the vehicle, on whose shoulders the mantle of maintenance falls and on whose head rests the responsibility of increasing the dollar-earning capacity of the vehicle.

All engines must be repaired, overhauled or rebuilt. When laying an engine out on the drafting-board, you must design

(1) A power generator on a par with or better than that of your competitor
(2) A powerplant that can be produced economically
(3) A powerplant that permits economical maintenance in the hands of the user

Maintenance Aspects

When we consider that these vehicles are dollar-earners and that they can only earn dollars when they are in working condition and their wheels are turning, we see why the owner is considering the maintenance aspect. Every day the vehicle is out of service for repairs means a loss of revenue. You know how your profits would be affected if the assembly department in your factory were out of commission for a period.

One fleet owner in the market for a number of vehicles has his engineers going over different makes of vehicle and measuring them with this maintenance yardstick. These engineers have gone so far as to have different units of the vehicle removed in their own service-station to get an accurate measurement of the maintenance factor. Only a few fleet-owners today are doing this but, after several years of experience in maintenance matters, many others are in a distinctly receptive mood and they soon will be compelled to take similar measures. One Mid-West company has a representative who has gone to many different cities to ascertain costs and study the situation in general. It is only within the last few years that comprehensive investigations of this character have been going on, when business conditions have required such a careful study of things.

Operator's Problems Should Be Studied

Examples of this kind constitute a message that the engineer cannot neglect. I repeat that the owner measures the performance of his vehicles in terms of earning capacity; and earning capacity generally is proportionate to the number of days the vehicle is in service, from the time it is purchased until it is discarded.

Some 18 months ago, I looked over the complete records of 10 or 12 different companies in one of our cities. It showed the number of days different makes of vehicle were in commission. It was surprising to me that some of the lower-priced vehicles were not in operation on an average 18 days per month. Other makes were in service 25 and 26 days a month. The engineer who will place his firm in the forefront is the one who is studying first-hand the problems of the operator and is designing with a view to reducing the transportation costs.

Cost Accounting and Fleet Operation

The consumer is studying his costs as never before. A few years ago, numerous fleet-owners had hopelessly inadequate cost-keeping systems. A little later they hired their own accountants and installed comprehensive systems. Today, many are calling into consultation expert accountants to determine how the losses can be reduced and greater efficiency attained. Five or six companies located in New York City, which employ very capable accountants regularly, have engaged outside firms of national reputation to make closer studies of their cost systems.

These consumers are meeting together in conventions. The subject of fleet operation is being put on the program; formerly it was given no consideration. Motor-transport matters are reaching the ears of the chief executives. In certain industries, such as department stores, a separate national organization of those responsible for the operation of the motor vehicles has been formed.

Privately Owned Service-Stations

A bit of evidence that shows how essential maintenance is in fleet operation is the work the fleet owners already have done to reduce its cost. The creation of the private service-station is a good example. Based on 8000 communications from fleet owners located in all parts of the Country, the numbers operating their own service-stations, classified according to the number of vehicles operated, are shown in Table 1.

TABLE 1—FLEET OWNERS WHO OPERATE THEIR OWN SERVICE-STATIONS

Number of Vehicles	Per Cent
10 or more	88.9
5 to 9	79.9
3 and 4	60.4
1 and 2	46.0

It was not difficult to understand the reason for the percentage for three and four vehicles. They are in relatively small places and are relatively high-priced trucks. Very often such a fleet is made up of at least three different makes of the highest-priced trucks. I feel sure that, when they come to buying more vehicles, such purchasers will begin the standardizing program, because their comments show that they realize the error of carrying stocks for three different makes of truck. Apparently they made their former purchases with the thought of making their own personal study of the vehicles. We might trace this back to the confusion created in their minds by the truck-builders' sales methods. It does seem unfortunate that an operator in a small town should load himself up with three different makes of vehicle and carry the maintenance load that goes with them.

The great number of private service-stations means that the fleet owners have determined to reduce the actual cost to them of repairing and overhauling and also the time a vehicle is out of commission during such work. The private service-station brings the transportation superintendent face-to-face with the design of the vehicles used. He notes the length of time needed to remove a generator designed so that the base of the crank-case must be taken off first or the radiator removed. He encounters the work that has to be done in replacing piston-rings. He has accurate records of the time required to grind valves on different makes of vehicle or to remove the carbon.

Why do these fleet owners have their own service-stations? Following are a few reasons taken direct from statements of those who operate only three or four trucks. What applies to the small fleet owner applies in greater degree to the large operator. Perhaps the first reason is the most important.

(1) It is of as much importance to have our own garage as to have our own stores
(2) We save 50 per cent by having our own garage
(3) We can watch our trucks better
(4) We can keep our vehicles in good operating condition at less cost
(5) More satisfactory work is done by our own repairmen
(6) The repair work done is more accurate
(7) We get repairs made when we want them
(8) It is cheapest in the long run; we have tried both plans
(9) It saves not only considerable time, but a vast amount of annoyance
(10) Our drivers take greater interest in our vehicles, because they know they are repaired by our own organization

Some of the large fleet owners have investments ranging between $100,000 and $300,000 in their service-stations and equipment. The vehicles must be kept in good condition. Repairs must be made between the time the vehicles check-in at 6:00 p. m. and checking-out time the following morning.

Possible Economies

As an example of how the fleet owner is studying the possible economies, the operator of 156 vehicles awoke to the fact that the method he used when having the vehicle painted kept it in the shop 3 weeks, although its overhauling could be accomplished in less than 1 week, due to the unit-repair system employed. He discovered that this involved a total of 468 idle weeks every 18 months with 156 vehicles. The vehicles are painted every 18 months and are also varnished 9 months after each painting. These 468 weeks equal 9 years; so, every 18-month period, there is the equivalent of a total idle time of 9 years for one vehicle. On a yearly basis, this idle period would be 6 years for one vehicle. Consequently, this operator will adopt a painting process by which the paint work on a vehicle can be done in 3 days.

The superintendent in charge of a fleet of more than 100 vehicles has difficulty with his good mechanics. They objected to getting under a dirty vehicle at all hours of the day and in all kinds of weather to make necessary repairs. These mechanics are leaders in their line and wish to work not more than 8 hr. per day and to work under conditions in keeping with their ability and the character of their work. The superintendent suggests that the engineer design the vehicle so that unit removals that call only for the services of workers capable of removing nuts and bolts will be practicable. Such work can be done at any hour of the day or night. The unit so removed can be sent to the repair-shop. There the mechanic can do the repair work under conditions favorable to the character of work. Such a plan seems to possess much merit. The value of this suggestion to the engineer lies in his realization of the problem with which the fleet operator is faced.

Fleet owners are recognizing that the appearance of the vehicle is a great factor in trade, and that a spick-and-span vehicle manned by a businesslike truckman is a great asset to the company. A large commercial

hauler in one of our big industrial centers made a close investigation over a period of years to determine the best means of getting business. He advertised in various channels and followed other methods, but the final analysis showed that he obtained 90 per cent of his business because of the good appearance of his vehicles on the street.

Future Equipment

What the future holds in the way of equipment on motor trucks and buses can be gaged only by the dollar-earning value of these devices. The motorbus, very much discussed at present, is really much more in a formative stage than is generally supposed. One builder of motorbuses, to meet the new period that demands new measures and too often new men, had his engineer ride for weeks on certain bus-lines to ask individuals what kinds of bus they wanted; at the same time, a sales representative was taking the same course in another section of the Country; and in a third area a bus driver was functioning similarly. The result was a complete reversal of thinking on the part of the builder. He rediscovered the fact that the people who travel pay the bill. They put up with uncomfortable seats, breathe impure air, pay doctors' bills for colds contracted because of inadequate ventilation and suffer from lack of rational heating. They experience the sapping of mental and physical energy due to these and other conditions. The builder learned that the public wants to ride in comfort. It is willing to pay for such service. He learned, regarding two of his own buses that operated over the same route, that the greater earner was the vehicle that gave the comfort the public demanded.

After having thus decided by public verdict the type of vehicle needed, the builder set out to sell such a vehicle. It was not a cheap type; rather, it was an expensive one that could not be sold on chassis specifications or a list-price basis. It depended upon its earning capacity. Some prospects asked the list price and the cost of operating, but the builder led them to the all-important fact of the earning capacity of the vehicle. If it will not earn profits it is too expensive at any price, and if it will show profits it is a good investment at any price. It is rather unusual that this argument had not been used previously, and it is not surprising that it has taken hold as quickly as it has. Other builders have told me the same story. When they presented their vehicles to sell at well over $8,000, the prospective customers said: "We cannot afford that." The answer was: "It is not what it costs; it is what it earns. If this vehicle can be operated for 20 or 21 cents per mile and your charges for repairs are a certain amount, it is easy to show possible earning capacities." In each case where vehicles were sold, several repeat-orders were received within the next 6 months. Here again we come face to face with transportation, which is the business for which a vehicle is designed, and the dollar-earning capacity that measures its success.

The traditions of the earlier days have proved to be a very great handicap. The companies that will come out ahead in the next few years are those that study the matter first-hand. This has certainly proved to be true in the motorbus field, and it will prove equally true in these days when the position of the motor truck is being consolidated by many of the fleet owners.

THE DISCUSSION

Chairman Benjamin S. Pfeiffer:—Mr. Beecroft has said that we must sell transportation instead of specifications. The customer knows what he needs in the way of transportation but is not interested in the specifications that go to make up the truck that will give him this result. He leaves the specifications to the builder as he would leave the selection of medicine to his doctor, since what he wants is results in both cases.

George H. Pride:—Lack of cost data became apparent while a number of us were working to develop the National Truck-Cost Accounting-System. At first I concealed my costs with great care. Then it dawned on me that the only kind of competition that is absolutely hopeless is the competition of ignorance. If a man does not know how much it is costing him to do business, you cannot compete with him because he cuts your price on the basis that he can do at least as well as you did and perhaps better. I reversed my policy and invited my competitors to look at my books; coincidentally, the National Truck-Cost Accounting-System was promulgated. I remember a meeting at the Automobile Club of America, at which either the owners or the men directly in charge of the operation of more than 400 trucks in New York City were present. The variation in cost of operation, as they assumed it, was very wide; almost 50 per cent between the highest and the lowest. When they explained how they compiled their statistics we found that, without exception, they made no allowance for the cost of idleness and several other elements. When you figure that all the fixed charges are pro-rated on a 300-day basis, and assume, as we did, that a truck which would be in operating condition for 80 per cent of the time is a masterly piece of mechanism kept up in a most unusual fashion, it would mean that you must compute it on a 240-day basis; that is, if computed on a 300-day basis we would have had to add 25 per cent more, an amount greater than most of us were figuring as our daily net profit per unit. Most of the men were aghast when this was made plain and they began to rectify the costs. Then a general stiffening in prices followed.

From the standpoint of price, many builders in the early days were afraid to have it known what the actual costs were, but the motor truck has become so firmly knit into the fabric of the Country that nobody need fear what the costs are. They should tell not how little the cost is, but how much the cost is to operate a truck. Just as soon as that is generally known and is made use of, the user will be put on a more firm financial foundation and eventually capital will be attracted more largely into the purchasing class; this business will then be stabilized to a much greater extent.

In 1919, when I solicited business from some of the large industrial organizations, I interviewed several that I had chosen carefully so that the overlapping of their peak loads would bring me on a median line of operation throughout the year. I explained to one company that I wanted to investigate its transportation in all the cities in which it had branches. I went out on this work very carefully and figured the price very conservatively; I figured 10 per cent net profit, which is a very reasonable percentage. When I presented my figures, the management agreed that my quotation was somewhat lower than the costs they derived from their own truck operation. However, they also explained that they were operating comparatively few cars and were relying upon owner-drivers to do their transportation. They agreed that these owner-drivers, through a lack of knowledge of operating costs, were charging less than the work cost and, therefore, could not persist in the business. They stated, nevertheless, that they would be compelled to utilize men of this type, endeavoring to secure new

owner-drivers as the previous ones were forced out of business. This company stated that it realized this was not a solid foundation on which to build its transportation requirements but that, owing to the fact that its business was highly competitive and also because its competitors were having their transportation requirements met in the same way, it would be compelled to continue this practice so long as its competitors persisted in it. The company said that it would far prefer to give its transportation business to a man who charges an amount sufficient to cover his costs and give him a reasonable profit, and that it believed its competitors felt the same way. However, none of the companies would enter into any such contract unless all the rest agreed to do so simultaneously.

H. L. HORNING:—No designer ever attains good design unless he translates his knowledge of design into terms that will fit in with human demands. That is an engineer's job. Any designer who believes that his design, on paper or in steel, is more important than the man's idea who is using it, has made a purposeless design. The most critical moment, after a design of any unit is finished, is when the organization gathers around and says, "Isn't it a peach?" Right then somebody should chloroform all of them, because it is only after the unit goes through actual service in the hands of human beings that one can say whether it will ever amount to anything.

In all transactions, whether they be of designing or the larger transactions in which business considerations apply, many parties must be considered. The designer, of course, has profits to think of; he always thinks of the profits of the company he is working for, even though he may think in terms of his own profits, his salary, but a profit has to be split and, unless the customer makes his profit, the designer has failed absolutely. The only question in any transaction is how to split the profit fairly.

Original, or first, cost is merely an item. The cost of maintenance and the little things that have to do with human demands pile up to a much greater sum-total. I try to impress our designers with the fact that what we can do with our job is not so important as what the fellow out in the field can do with it. For instance, we have always used flat belts. We know other belts are better than the flat type but, when a man wants a belt in an emergency, he wants to be able to get a substitute that is flat, such as leather reins from a stable, or cloth or something similar. As another instance, we found a packing for a water-pump that not only stopped leaking but would lubricate itself; and hence the grease-cup could be left off. But we considered: "What of the man in the country who has no packing just like this, who has to pack with a substitute and then has no grease-cup to keep his home-made packing lubricated?" In the field, the place where things go wrong, conditions must be such that operations can be maintained. You can go through the entire list of engine parts in that respect.

We have long neglected to have the electrical equipment in such a position that we can see what we are doing when adjusting the breaker-points. Almost invariably, the spark-plugs are in such a location that you have to break the porcelain to get them out. Push-rod nuts usually are located so that they are very difficult to set; it is so difficult to reset them that one of the great evils that has occurred in the last year, the burning-out of the exhaust-valves due to the higher speed, has arisen. People hate so much to adjust push-rods that they do not do it; the result is that the clearance reaches the point where the valves expand and burn-out. None but those who have wrestled with a spring and valve and spring clip and tried to get them all together at the same time can realize how difficult this is to do. One of the most necessary things to design along the line of service is some means that will allow valves to be taken out easily.

In connection with carbureters, I believe one of the greatest inventions yet to come is one that will allow a man to adjust a carbureter to the weather and prevent him from adjusting it to his own disposition. We have a continual quarrel between the men who believe in a carbureter that has no adjustments and the men who favor adjustable carbureters. A carbureter that has no adjustments possesses some advantages, but differing temperatures make adjustments almost necessary. If some adjustment can be made without depending too much on the human element, it will contribute wonderfully to the improved performance of trucks.

We have tried to commercialize the attainment of a high number of ton-miles per gallon. The carbureter and the drivers who deliberately use an over-rich mixture when a leaner mixture would give infinitely greater satisfaction in every respect stand in the way of real attainment along that line.

I wish to speak of lubricating oil in connection with service and maintenance; to call attention to what I believe is a fundamental. Good lubricating oil can be found in all oil sold but, on the other hand, the oil on both ends of the scale is not correct.

Lubricating oil today is constituted of three portions. The light end will not break-down, the middle is less stable and the heavy ends of the oil are the least stable. The light end will evaporate very rapidly, the middle portion will not evaporate so rapidly and the heavy ends will evaporate very little. You must compromise. The middle portion is the real lubricating oil. The time is coming, and it should not be far off, when the users of trucks will be willing to pay a higher price per gallon to get a lubricating oil containing less light-ends and less heavy-ends, so as to get increased mileage per gallon of oil. Such oil is available today, but in surprisingly small quantities. One can afford to pay $2 per gal. for a fine oil. The danger lies in the decision as to what constitutes a fine oil.

Temperature is an important maintenance factor. We are dealing with heat engines; heat is the problem in engines, from beginning to end. We have engines that have run 125,000 miles without any adjustment of the connecting-rod bearings; that is due entirely to the utilization of the proper temperature and oil. The average temperature of the cycle is high in these runs; therefore, the temperature of the combustion-chamber is high and a better vaporization of the charges going in results. With good oil the bearings have a chance and, in 125,000 miles, it is a question of the temperature of the cycle in the engine and the quality and the cleanness of the lubricating oil. It has something to do with the crankshaft size and something to do with the lubricating system, the areas and all that, but the temperature and the oil are the fundamentals that count. I believe that in the immediate future the engineering factors that have to do with the maintenance which we will build into trucks are considerations of temperature and lubricants. After that we may pay more attention to the manifold.

Few people realize the loss of gasoline mileage due to the viscosity of the lubricants used in the rear axles,

(*Concluded on p.* 538)

Practical Balancing of Engine Components

By A. A. Bull[1]

Detroit Section Paper *Illustrated with* Diagrams

REFERENCES are cited to previous theoretical discussions of engine balance prior to consideration of vibrations in four, six or eight-cylinder engines that may either be felt or heard in the car and result from lack of balance. Dynamic arrangement of the engine, unequal forces set up by the unequal weights of moving parts and vibration arising from elasticity or yielding of the parts themselves are the major causes of unbalance, of which the unequal weights of the parts are within the manufacturers' control.

Unbalance of the conventional four-cylinder engine is of considerable magnitude, due to the angularity of the connecting-rod that produces unequal piston motion at the upper and at the lower part of the stroke, the unbalanced force reversing itself twice per revolution and acting in a vertical direction. The actual magnitude of this force varies directly with the weight of the reciprocating masses and as the square of the speed. Hence, a reduction in the weight of the reciprocating masses has a direct effect upon the magnitude of unbalance and the use of aluminum pistons and light weights has a tremendous influence toward vibration reduction.

From a production standpoint, the influence of mechanical unbalance of the parts and variation in their weight that may create different unbalanced forces are of principal concern. Specific instances are illustrated and analyzed. The commercial balancing of crankshafts, flywheels, clutches and propeller-shaft assemblies is outlined, six and eight-cylinder-engine balance is considered and vibration-test results, in terms of actual measurement on the dynamometer and in the car, are presented. It appears that an engine in theoretical balance should have the reciprocating and the rotating parts balanced to close limits, but a more definite understanding of how this should be accomplished is highly desirable. Balancing of the engine components is essential, and reasonable tolerances can be established that can be adhered to commercially.

IN engine design, apart from the question of balancing and the theoretical considerations involved, some consideration of the extent to which the intentions of design are carried out in practice is necessary and it forms the subject of this discussion. It is useless to devote time and attention to the elimination of theoretical unbalance, and with it the vibrating tendencies, unless the proper methods are employed in manufacture to keep the factors affecting such balance and vibration under control. On the other hand, possibly it is unnecessary to expect or to require fastidious exactitude in the balance of parts in designs where the inherent unbalance already is of large magnitude.

Some of the theoretical considerations of the subject of engine balance which involved the question of the geometric layout or arrangement of the engine were discussed at a recent meeting.[2] The fundamental differences in the balance of four, six and eight-cylinder engines have been well covered before and are generally understood. In this discussion, we are concerned chiefly with the vibrations that may either be felt or heard in the car, and which are a result of lack of balance. Substantially, unbalance arises from the

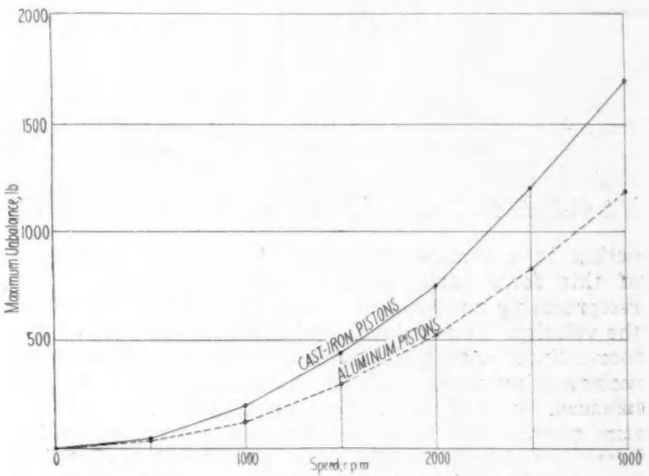

Fig. 1—Magnitude of the Vibrating Force in a Four-Cylinder 3⅜ x 4¾-In. Engine and Its Relation to the Speed

The Influence of the Aluminum Pistons on the Magnitude of the Unbalance Forces Should Be Noted. Another Feature That Should Be Commented Upon Is the Fact That the Vibration Does Not Become Worse in Direct Proportion to the Increase in the Speed. This Is Because at a Certain Speed, Usually about 1200 R.P.M., the Vibrating Force Is in Synchronism with the Engine Mass

(1) Dynamic arrangement of the engine
(2) Unequal forces set up by the unequal weights of moving parts
(3) Vibration arising from elasticity or yielding of the parts themselves

The manufacturing department has control over class (2), and the extent to which such control must be exercised will be understood best by a consideration of the problem of engine balance as a whole. It must be recognized first that the roughness or vibration felt in the car may be due to other causes than unbalance, and the extent to which it is observed depends largely upon the amount of unbalance and its relationship to the mass or weight of the engine. The possible synchronism of vibrations in the engine with other parts of the chassis will be affected to a large extent by the nature of attachment of the engine to the chassis and must be given careful consideration.

Unbalance of the Four-Cylinder Engine

Commencing with the four-cylinder engine of the conventional form, an unbalance of considerable magnitude exists. This is created by the angularity of the connecting-rod that produces unequal piston motion at the upper and at the lower parts of the stroke, the unbalanced force reversing itself twice per revolution and

[1] M.S.A.E.—Chief engineer, Northway Motor & Mfg. Co., Detroit.
[2] See The Journal, March, 1924, p. 355.

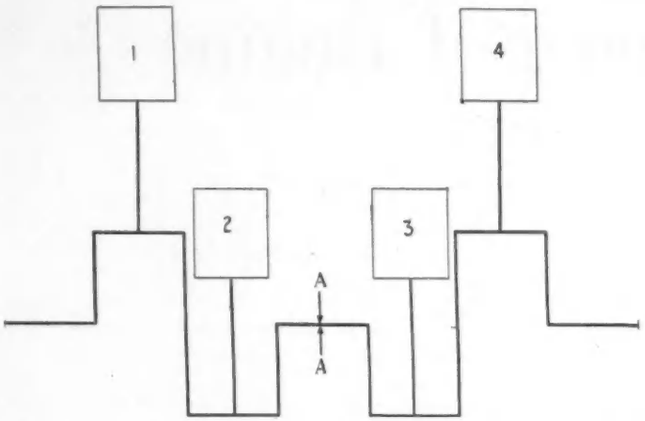

FIG. 2—HOW A VARIATION IN THE WEIGHTS OF THE PISTONS TENDS TO ROCK THE ENGINE AROUND THE AXIS OF SYMMETRY

If Pistons Nos. 1 and 4 Are of the Same Weight, They Will Have Equal and Opposite Turning Moments around the Axis of Symmetry *AA*. If However the Weights Vary, an Unbalanced Condition That Will Tend To Rock the Engine about This Axis Will Be Produced

acting in a vertical direction. The actual magnitude of this force varies directly with the weight of the reciprocating masses, and as the square of the speed, or the velocity. It is evident, therefore, in the case of the four-cylinder engine, that a reduction in the weight of the reciprocating masses affects the magnitude of the unbalanced forces directly. Consequently, the use of aluminum pistons and light weights has a tremendous influence on vibration. The actual extent of the vibrating force and its relation to speed is shown in Fig. 1.

One would naturally conclude that the higher the speed is, the worse would be the vibration produced; but this is not always true. The reason is that at a certain speed synchronism of the vibrating force with the engine mass occurs and, in most cases, this will occur first at a speed of about 1200 r.p.m. To set the engine in motion with a given periodicity requires a force proportional to the mass of the engine, the amplitude of vibration and its periodicity, so that, at definite speeds, a synchronized condition exists which produces a vibration that is easily observed and felt. The introduction of mechanical unbalance of parts may have an effect upon this.

It is possible that the engine may vibrate without being observed or noticed unless some other part of the chassis, such as the steering-gear, the brake levers or the windows, synchronizes with the engine vibration. For this reason, engine supports similar to those outlined by L. C. Freeman in his paper on Vibration in Four-Cylinder Engines[3] will efficiently prevent the effects of engine vibrations from being transmitted to the chassis. In addition to the fundamental inertia vibrations, the four-cylinder engine is affected due to torque alternations as a result of piston inertia, reference to which is also made later.

PRODUCTION REQUIREMENTS

From a production standpoint, the thing we are concerned with is the influence of the mechanical unbalance of the parts themselves and the variation in the weights of the parts which may create different unbalanced forces.

Fig. 1 shows the actual magnitude of the forces in an engine of say 3⅜-in. bore. Now consider the effect of a variation in these weights. Assuming the weights of the pistons to be equal, for instance, then pistons Nos. 1 and 4, attached to the crankshaft as shown in Fig. 2, will have equal and opposite turning moments around the axis of symmetry *AA*. If, however, the weights vary, an unbalanced condition will be produced which will tend to rock the engine about the axis *AA* before described.

Let us assume a variation of 2 oz. in the weights of these pistons; then, at different speeds, an unbalanced couple *A* or a tendency to rotate the engine about the axis *AA*, changing twice per revolution and of a magnitude shown in Fig. 3, will be set up. Resolving this couple into the actual force it impresses on the supports, we have the values indicated at the right which are directly comparable with the unbalanced force as indicated in Fig. 1. It can be seen that the force produced by this variation in weight is very small in its relationship to the total unbalance and, consequently, it would be assumed that it would not be noticeable in actual operation; hence, from a theoretical standpoint, the weight of piston to within ¼ oz. under such conditions would seem to indicate an absence of all sense of proportion. It is possible, however, that the introduction

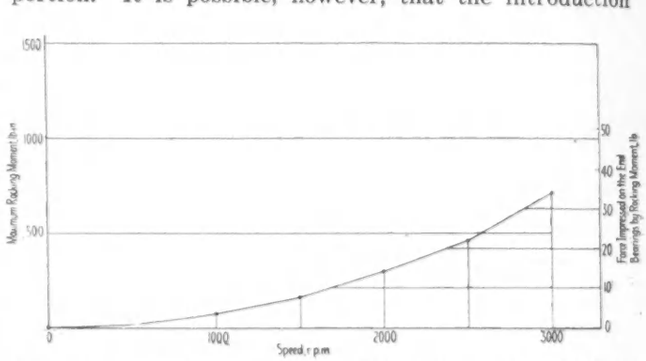

FIG. 3—ROCKING MOMENT RESULTING FROM 2-OZ. EXCESS WEIGHT IN ONE OF THE PISTONS OF A FOUR-CYLINDER ENGINE

The Excess Weight in the Piston Produces an Unbalanced Couple That Tends To Rotate the Engine about the Axis of Symmetry Shown in Fig. 2. This Changes Twice per Revolution and Has the Magnitude Shown. The Ordinates at the Right Show the Actual Force Impressed on the End Bearings by the Rocking Moment Which Is Directly Comparable with the Unbalanced Forces Shown in Fig. 1

of this unbalanced moment may introduce a vibration that, by reason of its periodicity, may synchronize more readily with the chassis, and particularly as it operates to its greatest extent in a vertical plane.

If we now consider that the weights of pistons Nos. 1 and 4 are the same but are different from those of pistons Nos. 2 and 3, which likewise may be equal, then no unbalanced couple or tendency to rock the engine exists; but the unbalanced inertia force, as a result of the difference in the piston masses of Nos. 1 and 4 and Nos. 2 and 3, will be changed slightly, in effect producing the same results as would occur if there were a static error in the crankshaft of similar weight. Static unbalance in the crankshaft, therefore, without dynamic unbalance, or couple, has no effect on the vibration. This leads us to the desirability of the balancing of the crankshaft, in which a similar unbalance to that of Fig. 3 may arise if dynamic unbalance exists in the shaft producing a couple about the plane of symmetry.

COMMERCIAL CRANKSHAFT BALANCING

Let us analyze the reactions on the crankshaft. First, we must have static balance before dynamic balance can be obtained. Static balance in itself is not really important but, without it, dynamic balance cannot be obtained. Static balance merely means that the weight or mass of material must be disposed equally on either

[3] See THE JOURNAL, April, 1924, p. 444.

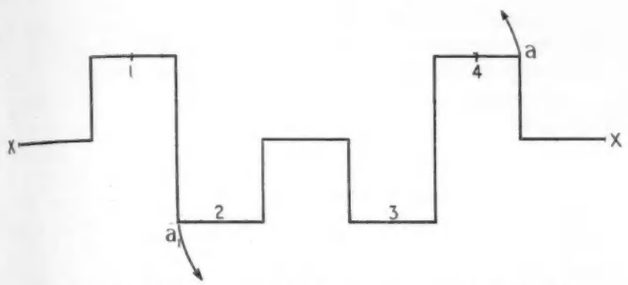

FIG. 4—DIAGRAM SHOWING THE REACTIONS ON A CRANKSHAFT

Static Balance, Which Merely Means That the Weight or Mass of Material Must Be Equally Disposed on Either Side of the Axis *XX*, Is Necessary if Dynamic Balance Is To Be Secured. The Mass May Not, However, Be Equally Distributed along the Shaft. While a Weight of 2 Oz. at *a* Can Be Balanced by a Similar Weight a_1 and Static Balance Obtained, This Condition of Weight Distribution Produces a Couple or Turning Effort Equal to the Force the Weight Will Produce at Different Speeds Multiplied by the Length. This Is Exactly the Same Condition as the Variation in Piston Weight Indicated in Fig. 2, except That in This Case the Couple Is Exerting Itself throughout the Whole Revolution and Consequently Has No Definite Plane of Movement or Periodicity and Is Not As Likely To Indicate Itself under Actual Operating Conditions

side of axis *XX* in Fig. 4, but it is evident that the mass may not be distributed equally along the shaft; for instance, assuming that a weight of 2 oz. at point *a* is balanced by a weight of equal amount at a_1, under which condition a static balance would be obtained. From this distribution of weight arises a couple or turning effort equal to the force the weight will produce at different speeds multiplied by the length, which is exactly the same condition as the variation in piston weight indicated in Fig. 2 except that, in this case, the couple is exerting itself throughout the entire revolution and, consequently, has no definite plane of movement or periodicity and is not as likely to indicate itself under actual operating conditions. Therefore, it is well to recognize the futility of accurate crankshaft balancing such as usually is considered essential if like accuracy in the balance of the pistons and the connecting-rods is neglected. In fact, the weights of the pistons and the connecting-rods, even to the distribution of the weight of the rod at both ends, is far more necessary than the dynamic balance of the crankshaft. In practice, the problem of selecting pistons to a close weight is difficult if, also, they must be selected for size, particularly when cast-iron pistons are used. With alloy or aluminum pistons and rods, the variation in weight between one and some other is a minimum and eliminates the necessity for any selection in this respect.

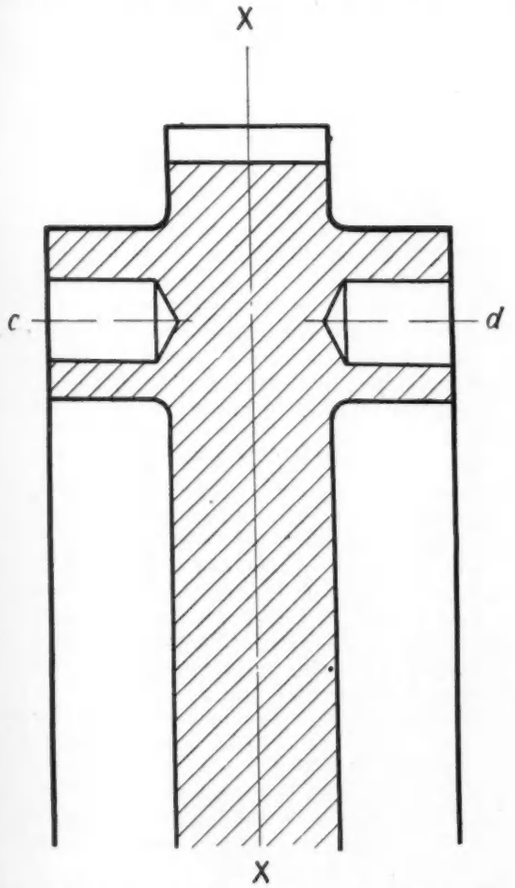

FIG. 5—DIAGRAM INDICATING HOW THE CORRECTION TO SECURE STATIC BALANCE IN A FLYWHEEL SHOULD BE MADE

Flywheel and Clutch Parts Are Not Likely To Be Affected Dynamically to Any Appreciable Extent on Account of the Short Axial Dimension and Can Therefore Be Satisfactorily Balanced Statically Only. In Correcting for Static Balance, Equal Amounts of Material Must Be Removed from Both Sides of the Vertical Axis *XX* as at *c* and *d*. If the Material Is Drilled Out on One Side of the Wheel Only, a Considerable Dynamic Error Can Be Introduced

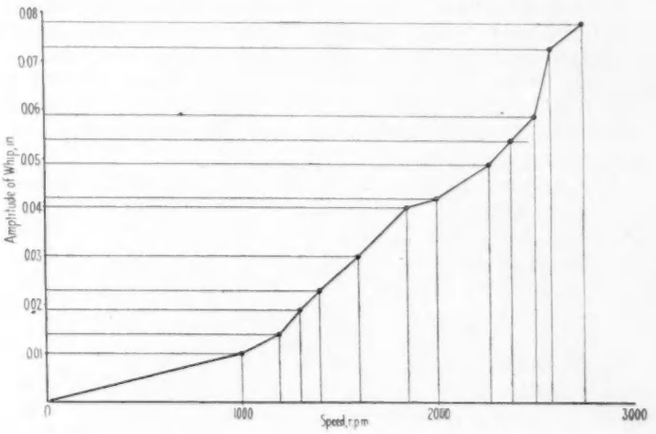

FIG. 6—RELATION BETWEEN CRANKSHAFT WHIP AND SPEED

Even without the Addition of Connecting-Rods and Pistons a Balanced Crankshaft Will Deflect by Reason of Its Rotation, the Magnitude of This Whip Varying at Different Speeds

What constitute commercial balancing limits for an engine crankshaft? With an accuracy of dynamic balance within 5 oz-in. in a shaft of the type indicated in Fig. 4, the weight variation would be 0.145 oz.

The tolerances specified and the accuracy actually attained depend upon the methods used for obtaining the balance. Not so long ago, and particularly with crankshafts that were machined all over, it was considered sufficient to establish a static balance only; but this can hardly be considered a satisfactory method today in many cases, because no guarantee of an equal distribution of weight along a crankshaft forging is possible. This is effected largely by the method used in establishing the center of the shaft. With the usual methods of removing the stock, the operator cannot be depended upon to remove the material equally at the proper points in order not to introduce dynamic instability. In obtaining static balance, prior to dynamic balance, the parallels or ways must be set-up accurately and be true in the machine. For dynamic balance, if such is necessary, actual measurement of the extent of unbalance should be made, and in no case is it proper to rectify the unbalance without checking it up afterward.

Flywheel and Clutch

Flywheel and clutch parts can be balanced satisfactorily for static balance only, as they are not likely to be affected dynamically to any great extent on account of the short axial dimension, but, in checking and rectifying for static balance, a considerable dynamic error can be introduced into the flywheel if the material is drilled out on one side of the wheel only, which is frequent practice. In correcting for static balance, an equal amount of material must be removed from both sides of the vertical axis *XX*, as indicated in the Fig. 5 at *c* and *d*. Preferably, flywheels and crankshafts should be balanced separately and, with reasonable accuracy in the flange and the pilot of the crankshaft and the flywheel, respectively, the run-out will not be sufficient to introduce any serious unbalance.

Six-Cylinder-Engine Balance

Let us refer now to the six-cylinder engine, in which no resultant inertia unbalance by reason of the location of the crankpins is present, and assume the reciprocating parts to be of equal weight. The resultant balance is obtained by virtue of the attachment of the reciprocating masses to the shaft, and the independent forces produced are transmitted and equalized, one with the other, through the shaft itself; consequently, they produce a stress and a deflection in the shaft.

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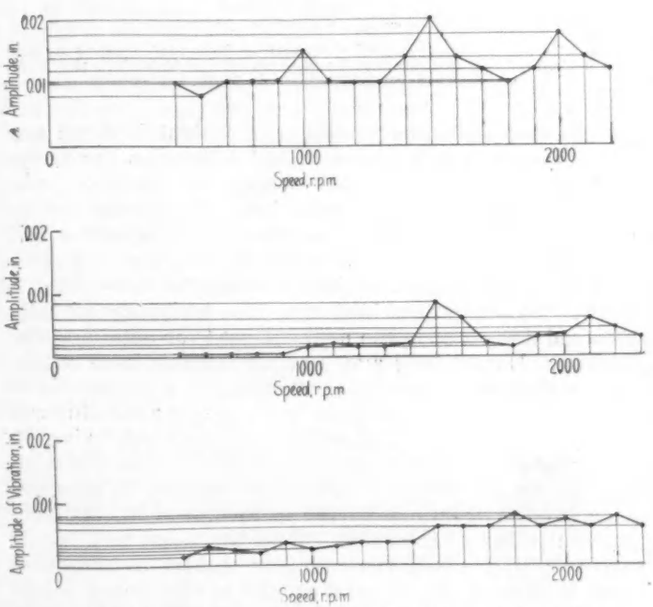

Fig. 7—Some Results of Tests To Measure the Amplitude of Vibration Due to Unbalanced Parts

The Top Diagram Shows the Horizontal and Vertical Vibrations of an Engine Having Inherent Unbalanced Forces. A Similar Engine with the Inertia Unbalance Completely Eliminated but Having a Critical Torsional Disturbance at One Speed Gave the Results Shown in the Middle Diagram. How the Installation of a Vibration Damper Eliminated the Critical Period Is Shown in the Diagram at the Bottom. The Vertical and the Horizontal Scales Are the Same in All Three Diagrams, Thus Enabling Comparisons To Be Made Readily

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Propeller-Shaft Assembly

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The extent to which a crankshaft deflects by reason of rotation, even without the addition of rods and pistons, is indicated in Fig. 6, the deflection produced at the different speeds with the balanced shaft being shown. In balancing crankshafts dynamically it is evident that, if the speed at which it is rotated is too high, vibrations will then be produced by "whip" which are not necessarily a result of dynamic unbalance.

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wood timbers at the rear and had flexible support in the front so that the engine could move in response to the unbalanced forces. Movement was then measured with a micrometer attachment having a connection with an electric circuit, thus indicating when the contact was made.

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The same engine referred to was then placed out of balance purposely by attaching two weights on the crankshaft of 2½ oz. to produce a dynamic unbalance of 107 oz-in. Similarly, a 3-oz. weight was attached to the flywheel on one side to introduce a static unbalance of 21 oz-in. Running the engine under the same conditions, the vibrations produced are also shown in Fig. 8.

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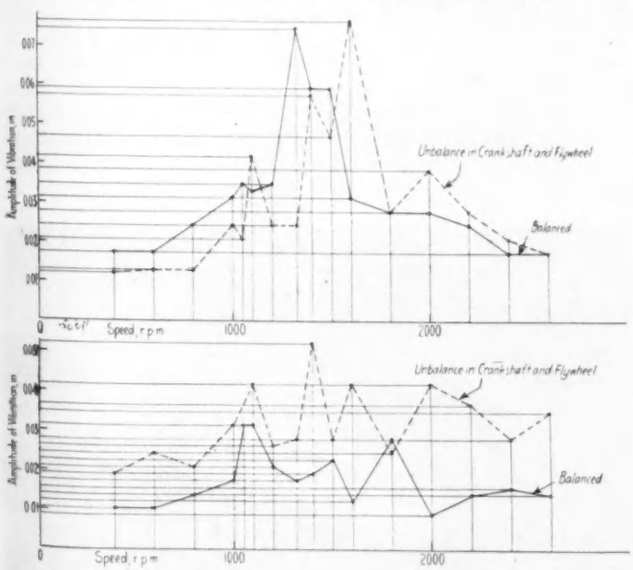

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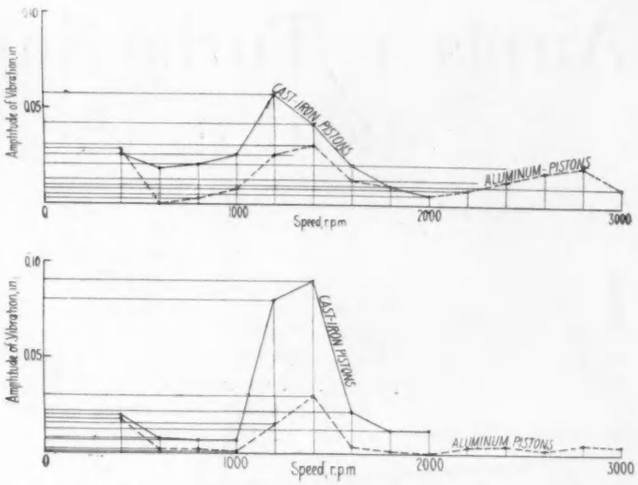

FIG. 9—THE VIBRATION OF A 3⅜ X 4¾-IN. SIX-CYLINDER ENGINE WHEN EQUIPPED WITH CAST-IRON ALUMINUM PISTONS
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In the case of balancing machines that do not record the actual unbalance and depend for accuracy entirely upon the feel or the vision of the operator, there is no guarantee of uniformity, although a balanced sample is used for a standard.

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No doubt we will have more information from the manufacturers of balancing equipment on the methods that can be employed to secure the proper results; and, similarly, representatives of the manufacturing department perhaps will give us some indication of the trouble they experience and the methods by which the trouble can be eliminated. Balancing of the engine components is really essential, and reasonable limits or tolerances can be established which can be adhered to commercially.

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Flywheel and Clutch

Flywheel and clutch parts can be balanced satisfactorily for static balance only, as they are not likely to be affected dynamically to any great extent on account of the short axial dimension, but, in checking and rectifying for static balance, a considerable dynamic error can be introduced into the flywheel if the material is drilled out on one side of the wheel only, which is frequent practice. In correcting for static balance, an equal amount of material must be removed from both sides of the vertical axis *XX*, as indicated in the Fig. 5 at *c* and *d*. Preferably, flywheels and crankshafts should be balanced separately and, with reasonable accuracy in the flange and the pilot of the crankshaft and the flywheel, respectively, the run-out will not be sufficient to introduce any serious unbalance.

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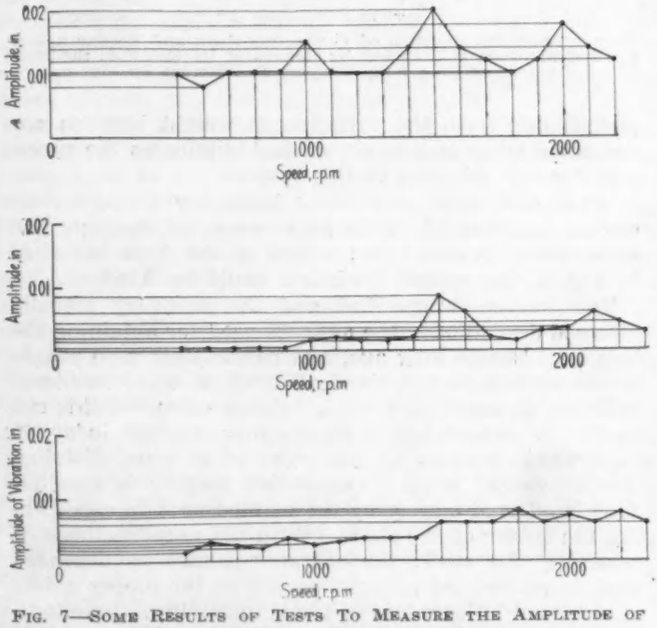

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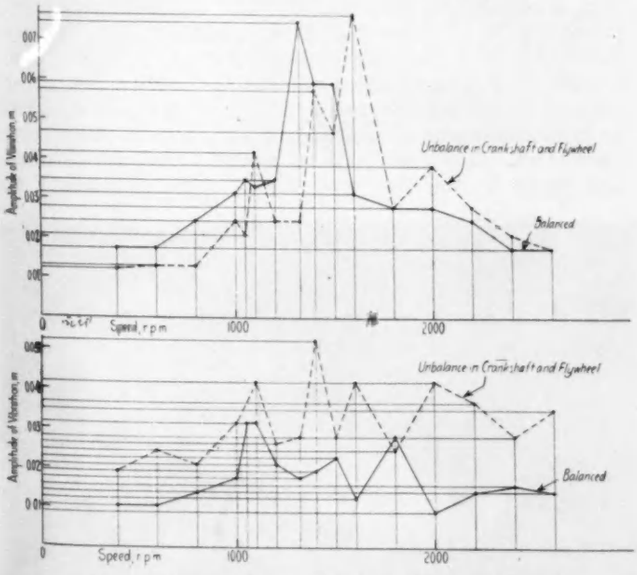

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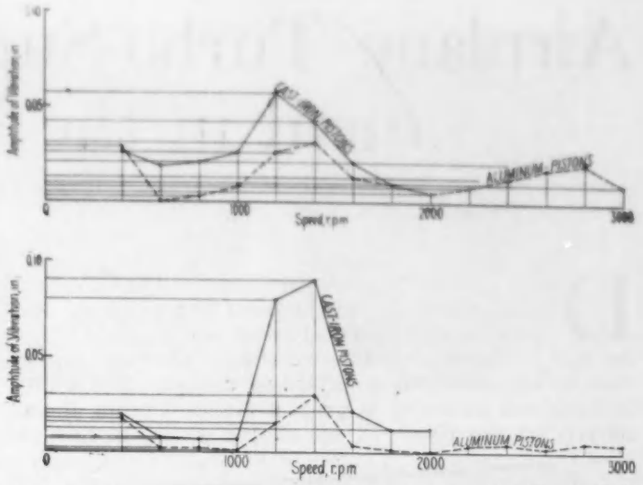

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Airplane Turbo-Supercharger Development in the United States

By DAVID GREGG[1] *Illustrated with* CHARTS AND PHOTOGRAPHS

DEVELOPMENT of superchargers in this Country was started by the demand for increased airplane performance at great altitudes. During the war the airplane that could climb faster and higher than its opponent had a decided advantage. The ability to climb and maneuver at great altitudes depends almost entirely on the power of the engine which, in turn, is governed by the weight of fuel and air taken into the cylinders at each stroke. As the engine reaches altitudes where the density of the air is less, the weight of the charge decreases and the power is reduced. This loss of power is apparent when one considers that a Liberty engine which will develop more than 400 hp. at sea level can maintain but 200 hp. at 15,000 ft., and only 87 hp. at 25,000 ft.

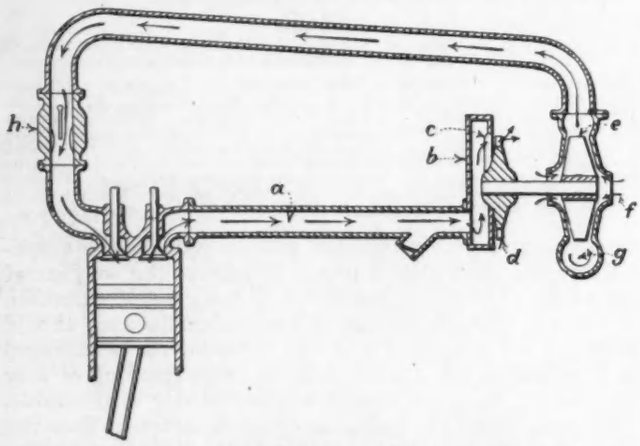

FIG. 1—DIAGRAM ILLUSTRATING THE OPERATION OF A TURBO-SUPERCHARGER

The Exhaust Gas from the Engine Is Led through a Manifold, *a*, into the Nozzle Box *b*, That Contains a Series of Nozzles *c*, through Which the Gas Expands and Attains a High Velocity before Entering the Buckets of the Turbine Wheel *d*, Which It Drives at High Speed. Air Enters the Impeller *e* through the Inlet *f* at the Center and Is Thrown by Centrifugal Force to the Tips of the Blades where a Series of Vanes Convert the Velocity of the Air into Pressure and Guide It in a Spiral Path, as Shown at *g*, to the Supercharger Outlet and Finally to the Intake of the Carbureter *h*

Increasing engine power at altitude was first attempted by using high-compression engines that were run at partial throttle on the ground and could not be opened-up fully until an altitude of perhaps 5000 ft. had been reached. This method of maintaining the power was effective at small altitudes, but it was impractical for altitudes greater than from 6000 to 7000 ft. Some method was necessary by which the engine could be supplied with air at sea-level pressure at any desired altitude. This is the function of the supercharger, which is merely a mechanical device to pump air at sea-level density to the engine regardless of the surrounding atmospheric conditions.

SUPERCHARGER TYPES

Reciprocating, rotary and centrifugal devices constitute the three usual types of air pump, or supercharger. The centrifugal type is best adapted to airplane use on account of its simplicity, light weight and freedom from pulsation. Several methods of drive are possible. The supercharger may be connected to a separate engine; it may be gear-driven from the engine that it supercharges, or driven by a gas turbine using exhaust gas. The gas-turbine method has had the greatest development and has been the most successful. The engineering division of the Air Service is experimenting with a number of types of gear-driven supercharger and it has obtained many valuable data on their performance; however, only the gas-driven type or turbo-supercharger will be considered at present.

SUPERCHARGER OPERATION

Fig. 1 is a schematic view of the way such a supercharger operates. The exhaust gas from the engine is led through a manifold *a* into a nozzle box *b* that contains a series of nozzles *c*. Through these nozzles the gas expands and reaches a high velocity before entering the buckets of the turbine wheel *d*, which it drives at high speed. Air enters the impeller *e* through inlets *f* at the center and is thrown by centrifugal force to the tips of the blades. At this point, a series of vanes surrounding the impeller converts the velocity of the air into pressure and guides it in a spiral path to the supercharger outlet and then through an air-cooler into the carbureter intake. While the principle is simple, many difficulties have been encountered in the course of the development.

One serious difficulty was the fact that the gas turbine operates at temperatures as high as 1500 deg. fahr. Fig. 2 is a night photograph taken of the turbo-supercharger. The exhaust-manifolds and the nozzle box are white-hot, and the turbine is rotating at more than 20,000 r.p.m., surrounded by the hot gases. A great amount of research and experimental work was required to produce a material that would withstand such extreme conditions. Turbine buckets would frequently stretch and break on the very first flight. The photograph at

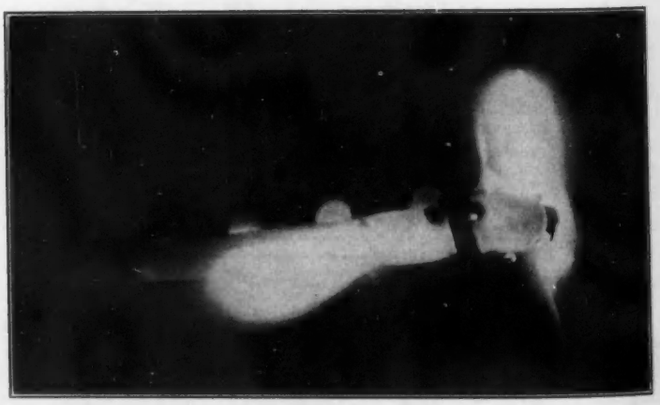

FIG. 2—NIGHT VIEW OF A TURBO-SUPERCHARGER

The Exhaust-Manifolds and the Nozzle Box Are White Hot from the High Temperature of Operation, 1500 Deg. Fahr., and the Turbine Is Surrounded by the Hot Gases and Is Rotating at a Speed of over 20,000 R.P.M.

[1] S.M.S.A.E.—Research engineer on superchargers, engineering division of the Air Service, McCook Field, Dayton, Ohio.

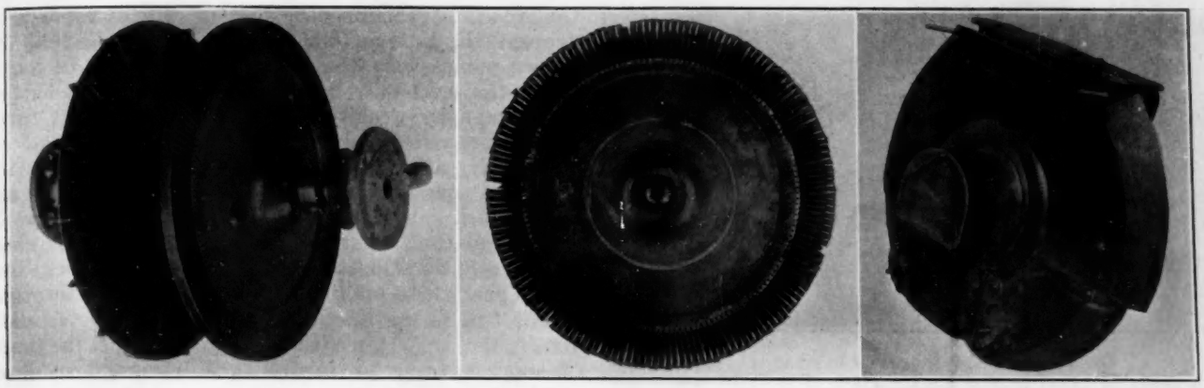

FIG. 3—THREE VIEWS OF THE ROTATING ELEMENT OF A TURBO-SUPERCHARGER SHOWING THE TURBINE WHEEL AND THE AIR IMPELLER

The View at the Left Shows a New Wheel, While the Middle One Indicates How the Turbine Buckets Have Stretched and Warped from the Intense Heat and the Centrifugal Force after Being Operated for a Few Minutes at High Speed and Excessive Temperature. How This Difficulty of Overheating and Stretching Was Overcome by Grinding Off the Bucket Shrouds To Lighten the Dead Weight of the Buckets and Decrease the Stress Due to Centrifugal Force Is Indicated in the Photograph Reproduced at the Right

the left of Fig. 3 shows a new turbine-wheel and the middle view shows the same wheel after operating at high temperature for but a few minutes. The difficulty of overheating and stretching was met in two ways. The first method, which is now being used on Form D or nose-type superchargers, is to grind off the bucket shrouds as shown in the photograph at the right of Fig. 3, thus lightening the dead weight of the buckets and decreasing the stress due to centrifugal force. The second method involved the complete redesign of the super-

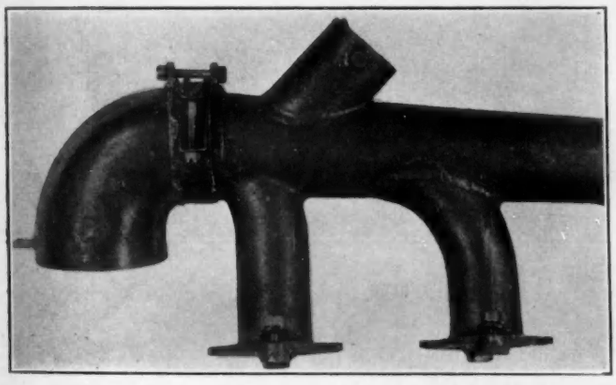

FIG. 4—A FLEXIBLE EXHAUST-MANIFOLD CONNECTION

This Connection Was Developed To Overcome the Warping and Cracking of the Manifold Resulting from the Passage of the Hot Exhaust-Gases. The Sections Were Wrapped with Asbestos Tape and Covered with a Band Clamp, Making a Joint That Was Easily Assembled and Allowed the Manifold To Expand or Contract over a Wide Temperature Range

charger, in which the turbine wheel was overhung and exposed to the propeller slipstream. This arrangement was called the side-type supercharger.

The hot exhaust gases warped and cracked the nozzle boxes and manifolds and made it difficult to keep the various joints tight. A gradual improvement in the design of the nozzle box and in the methods of manufacture, particularly the welding, successfully overcame these difficulties. The exhaust manifolds were redesigned with flexible expansion-joints, as shown in Fig. 4. The sections were wrapped with asbestos tape and covered with a band clamp, thus making a joint that is assembled easily and that allows the manifold to expand or contract under a wide range of temperature comparable to that encountered in airplane flying.

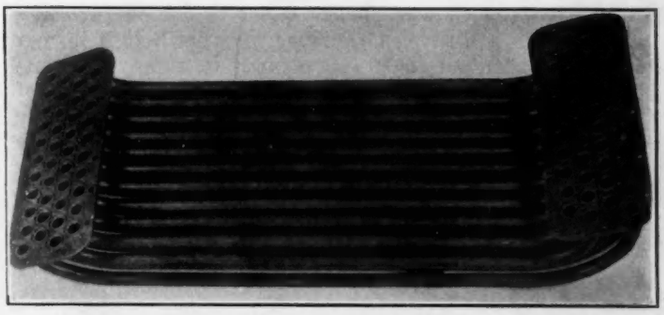

FIG. 5—ONE TYPE OF AIR COOLER USED ON THE NOSE TYPE OF TURBO-SUPERCHARGER

This Design Consists of a Series of Steel Tubes Through Which the Air from the Supercharger Passes and Gives Up the Heat It Contains as a Result of Compression

AIR-COOLER AND FUEL SYSTEM

When the air is compressed by the supercharger, its temperature is raised above the point at which the engine operates best; hence, an air-cooler is necessary. Several different types of air-cooler were tested, and two main designs were adopted. One design consists of a series of steel tubes through which the air passes, as shown in Fig. 5. The other design is a honeycomb radiator, shown in Fig. 6, that is similar to a regular water-cooled radiator. The honeycomb type is more compact and has somewhat less head-resistance.

As in the other lines of engineering development, progress frequently depends upon the development of accessories. This has been the case with superchargers. The first accessory to require attention was the fuel system. At that time fuel was supplied to the car-

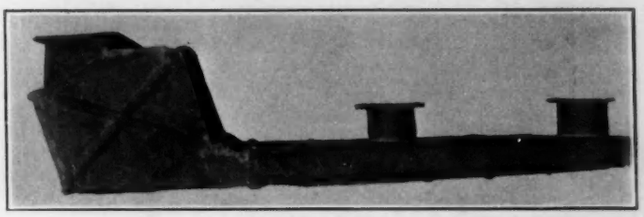

FIG. 6—A HONEYCOMB TYPE OF AIR COOLER

This Air Cooler, Which Was Constructed by the Engineering Division of the Air Service for a 35,000-Cu. Ft. Supercharger, Has a Core Similar to a Water Radiator and Is Very Effective in Cooling the Supercharger Air. This Type Is More Compact than the One Shown in Fig. 5 and Has Somewhat Less Head Resistance

FIG. 7—OXYGEN SUPPLY SYSTEM
The Oxygen Is Piped from a Supply Flask to a Valve Where the Pressure Is Reduced from 2000 Lb. per Sq. In. to a Few Ounces and from There Passes through a Coil in the Radiator Expansion-Tank Where the Hot Water Warms the Oxygen. A Flexible-Tubing Connection Leads to the Pilot's Helmet, the Supply Being Regulated To Suit His Needs by Opening and Closing the Reducing Valve

bureters by air pressure. As the pressure of the air in the carbureter was always equal to the surrounding atmospheric pressure, a pressure of from 2 to 3 lb. per sq. in. in the fuel tank was enough to supply the carbureter under all conditions; however, the addition of the supercharger caused a difference in pressure in the carbureter and the surrounding air at altitude and made it necessary to use so great a pressure in the fuel tank that this system was unsafe. Fuel pumps were then tried; they were mounted directly on the engine, usually above the level of the fuel in the tanks. At great altitudes it was found that the pumps could not lift the volatile gasoline, because it would vaporize and prevent the pumps from functioning properly. Wind-driven pumps were then used, as they could be mounted below the level of the tanks. The gasoline was fed to the pumps by gravity and then was pumped through a pressure-relief valve to the carbureter. The relief valve was entirely automatic in action, a spring maintaining a constant pressure of from 3 to 5 lb. per sq. in. on the fuel, and an air line on the top of the valve leading from the supercharger maintained supercharger pressure in addition to that of the spring. In this way it was possible to obtain a constant difference in pressure on the fuel in the line leading to the carbureter and the air in the carbureter bowl, regardless of the amount of supercharging or the altitude. The latest development in the fuel system for supercharged engines is a gear fuel-pump driven from the engine by a flexible shaft. These pumps can be mounted lower than the level of the fuel in the tanks; they are positive in operation and will undoubtedly replace the wind-driven system in time.

One of the early difficulties was the overheating of the engine due to inadequate cooling systems. The cooling water leaving the engine should be kept at about 80 deg. cent. (176 deg. fahr.) to obtain the best operating conditions. The boiling-point of water decreases approximately 1 deg. cent. (1.8 deg. fahr.) for each 1000-ft. increase in altitude; so, at a 20,000-ft. altitude, the cooling water would boil away rapidly under ordinary running conditions. To prevent this, the cooling system was sealed and two valves were inserted in the radiator expansion-tank. One was arranged to open if the pressure within the cooling system exceeded a safe amount; the other would open and permit air to enter the cooling system if a sudden cooling or loss of water should create a partial vacuum inside the system. This arrangement overcame virtually all the difficulties formerly experienced with the cooling of supercharged engines and has been used successfully on many different installations in various types of airplane.

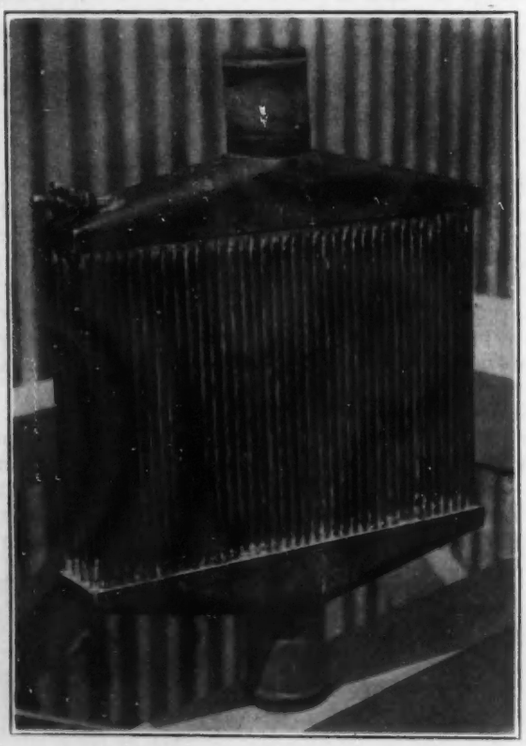

FIG. 8—HOT-WATER RADIATOR DEVELOPED TO KEEP THE COCKPIT COMFORTABLY WARM IN COLD WEATHER
This Arrangement, Which Is Being Incorporated in All Experimental Airplanes Used for Extreme Altitude Flying, Consists of a Number of Radiator Tubes through Which a Certain Quantity of Hot Water Leaving the Engine Is By-Passed. By Reaching Forward the Pilot Can Warm His Hands on the Heater Which Is a Great Advantage in Altitude Work

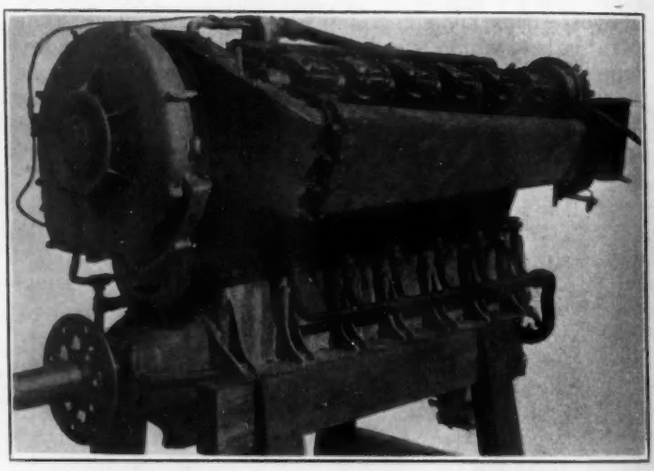

FIG. 9—THE ORIGINAL SIDE TYPE SUPERCHARGER
In This Supercharger Which Was the First Effort Made To Overcome the Defects of Former Types and To Provide a Compact and Readily Adjustable Outfit, the Compressor Casing Was Turned Sideways and Mounted on the Side of the Engine, Thus Decreasing the Head Resistance. Other Improvements Were the Overhanging of the Turbine Wheel and the Locating of the Nozzle Box between the Compressor Casing and the Nozzle Box Where the Gases Were Discharged through the Wheel Directly into the Atmosphere. As the Turbine Wheel Was Exposed to the Propeller Slipstream the Exhaust Gases Were Blown Away and the Wheel Was Kept Cool. The First of These Units Was Mounted on a 300-Hp. Engine and Flown for over 50 Hr. without the Slightest Attention

Spark-Plugs and Ignition

Spark-plugs and ignition systems came in for their share of attention. Mica plugs with large electrodes are preferred to porcelain ones; if the porcelain should break, pieces might be blown out through the exhaust into the supercharger turbine and undoubtedly would wreck the entire wheel. A number of similar cases occurred in which the turbine was damaged badly by broken pieces of porcelain. Large-sized electrodes carry away the heat and keep the points cool enough to prevent preignition. Magneto ignition has proved unsatisfactory because, at great altitudes, the current will jump either the safety-gap of the magneto or one of the many air-gap insulations, rather than at the points of the spark-plugs. The battery system has been more successful but, for regular flying at extremely great altitudes, special insulation is necessary to prevent leakage across air-gaps because their resistance decreases with the density of the air.

Propeller Types

The performance of supercharged airplanes has been retarded by a lack of suitable propellers. On account of the constant torque of a supercharged engine and the decreasing torque required to drive the propeller, due to the decreasing density of the air at altitude, the speed of the engine would increase; this made it necessary to use a large propeller at the ground to prevent the engine from racing at altitude. Numerous attempts have been made to build a successful variable-pitch propeller. A number have been constructed and flown with partial success, but the fixed propeller is more efficient and gives better performance at the present stage of development. In time, however, some form of variable-pitch propeller will become available; with it better airplane performance may be expected.

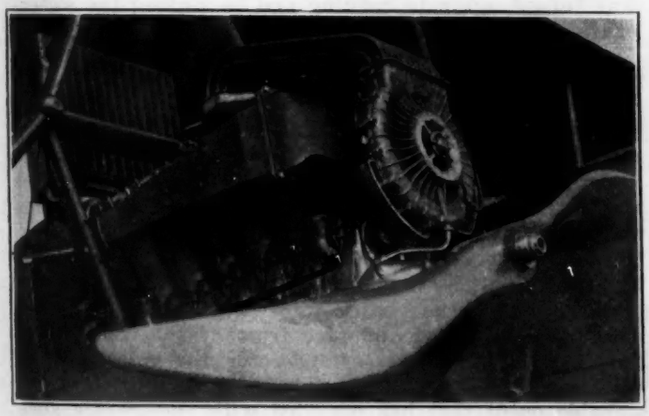

Fig. 10—The Form B Supercharger, a Later Development

In This Supercharger the Turbine Speed Was Increased from 22,000 to 34,000 R.P.M. and an Overspeed Test Was Made at 41,000 R.P.M. The Centrifugal Force to Which the Buckets Were Subjected in This Test Was 1750 Lb. High-Chromium Steel, Which Will Not Scale in the Presence of the Hot Exhaust-Gases, Was Used for the Buckets, and the Rotor, Which Weighs Only 20 Lb., Was Machined from a 250-Lb. Steel Forging. The Complete Supercharger Weighs 170 Lb. and a Steam-Driven Commercial Air Compressor of the Same Capacity Would Weigh Approximately 5000 Lb.

Oxygen-Supply System

One accessory essential to the successful operation of the supercharged airplane is a thoroughly reliable oxygen system. In the early flights at great altitudes, pilots and observers were hampered greatly by the lack of a proper system of oxygen supply. Discarding all attempts at an automatic-supply regulator, a manual

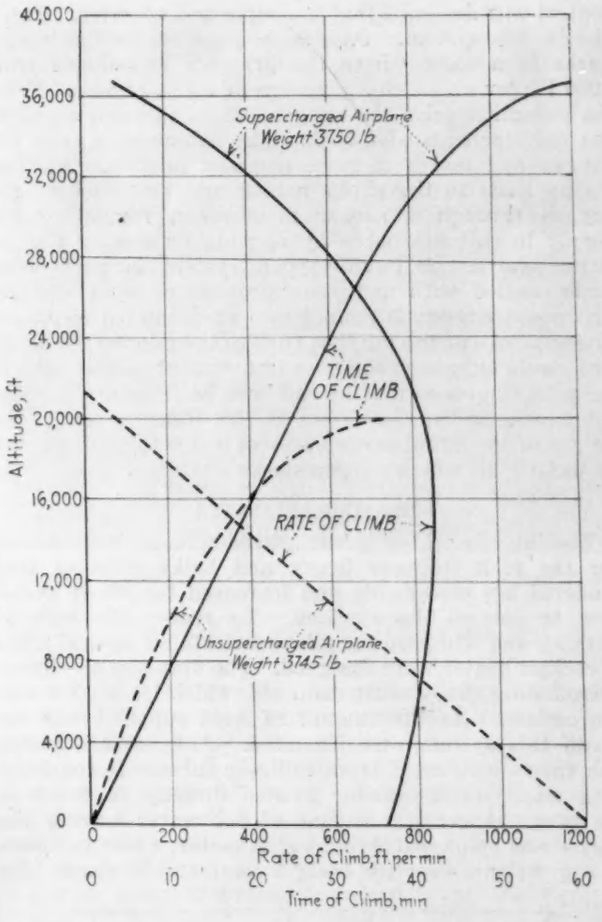

Fig. 11—Flight Test of a Two-Seater LePere Airplane Before and After Being Equipped with the Supercharger Illustrated in Fig. 10

Without the Supercharger This Biplane Had an Absolute Ceiling of 21,500 Ft. and a Speed at That Altitude of 74 M.P.H. The Addition of the Supercharger Increased the Ceiling to over 35,000 Ft. and the Speed at That Height Was 132 M.P.H.

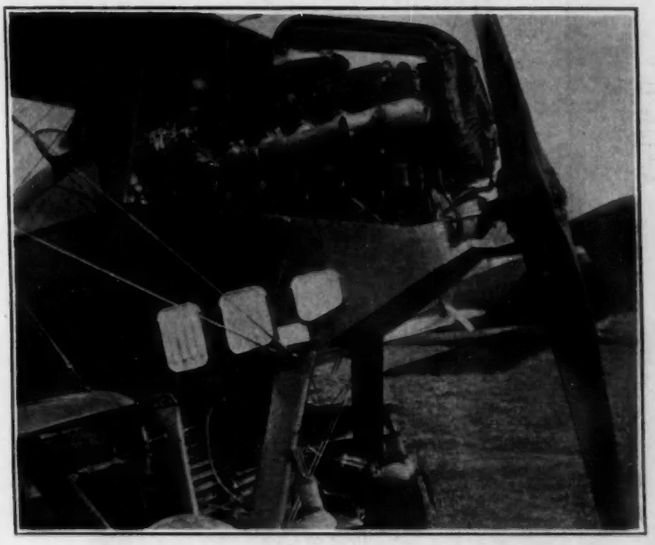

Fig. 12—The Form D Supercharger

This Was Developed for Use on the Martin Bombing Airplane. After the Preliminary Tests Had Been Completed One of These Airplanes So Equipped Twice Broke the Three-Man World's Altitude Record

control was designed that is simple and effective. Fig. 7 shows this system. Oxygen is piped from the supply flasks to a valve where the pressure is reduced from 2000 lb. per sq. in. to a pressure of a few ounces. From the reduction valve the oxygen passes through a coil in the radiator expansion-tank. The hot water warms the oxygen and makes it more pleasant to take. Flexible tubing leads to the pilot's helmet and he "smokes" the oxygen through a rubber mouthpiece, regulating the supply to suit his needs by opening or closing the reduction-valve. A liquid-oxygen system is now being experimented with and gives promise of some success. The liquid oxygen is poured into an insulated container having a tube at the top that runs to the pilot's face mask. The liquid oxygen vaporizes and flows out of this tube to the pilot's mask so that he can breathe it naturally without having to "smoke" it as in the other system. The weight of the liquid-oxygen system is much less than that of the one in which oxygen flasks are used.

Heating Apparatus

The intense cold at great altitudes made it necessary for the pilot to wear heavy and bulky clothing that hindered his movements and increased the effort necessary to control the airplane. To reduce the bulk of clothing and still keep the pilot comfortable, several types of cockpit heater were designed. The first was a cylinder surrounding the exhaust-manifold, which let hot air into the cockpit. As the amount of heat supplied was too small, this system was discarded. A hot-water heater was then constructed from radiator tubes. It consisted of a small water-radiator located directly in front of the pilot. A certain amount of hot water leaving the engine was by-passed through this heater, which is shown in Fig. 8; this kept the cockpit comfortably warm. By

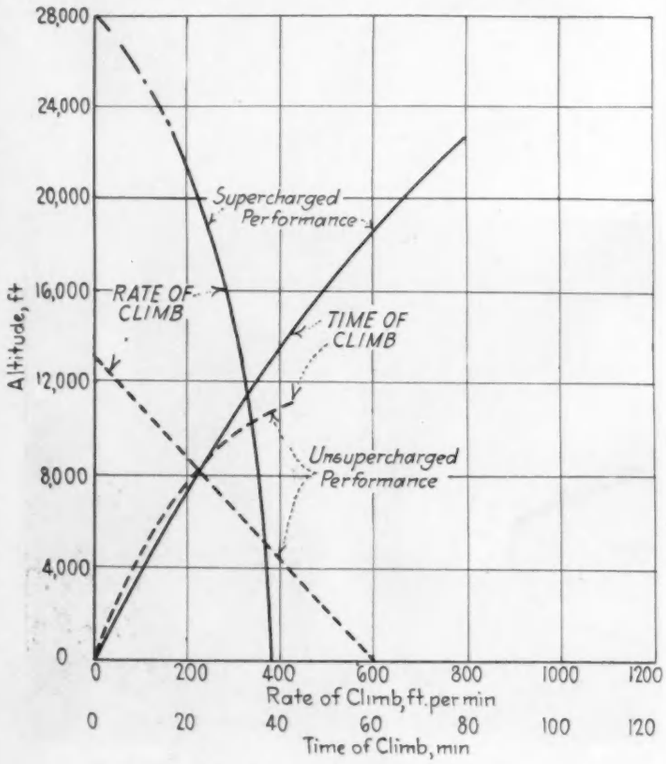

Fig. 13—Performance Curves of the Martin Bombing Airplane without Military Load

The Installation of the Form D Supercharger More Than Doubled the Absolute Ceiling of the Airplane and Its Speed at Altitude Was Also Greatly Increased

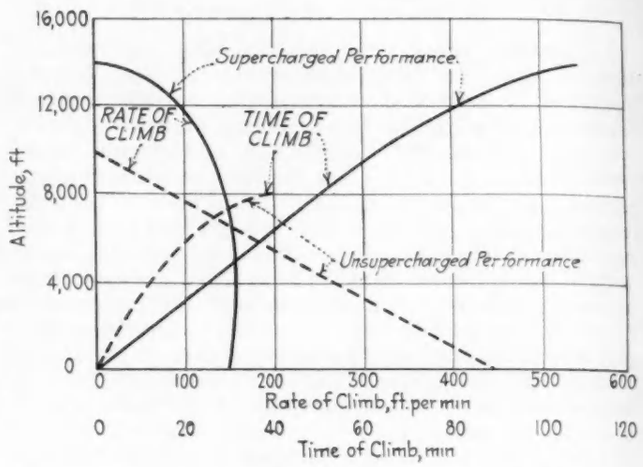

Fig. 14—Performance Curves of a Martin Bombing Airplane with Full Military Load

The Airplane in These Tests Weighed 12,027 Lb. and It Reached an Altitude That Was Approximately Double That of the Standard Airplane

reaching forward the pilot could warm his hands on the heater, and this was a great advantage in altitude flying. This system is being incorporated in all experimental airplanes used for extreme altitude flying.

Side-Type Supercharger

After these various accessories had been developed to a point at which they operated satisfactorily, attention was turned again to refining and perfecting the supercharger itself. The side-type supercharger was designed in an attempt to eliminate as many of the defects of former superchargers as possible and to provide a compact and readily adjustable outfit. The compressor casing was turned sidewise and mounted on the side of the engine as shown in Fig. 9; this decreased the head-resistance to a considerable extent. The turbine wheel was overhung. The nozzle box, located between the compressor casing and the turbine wheel, discharged its gases through the wheel and directly into the atmosphere. As the turbine wheel was exposed to the propeller slip-stream, the exhaust gases were blown away and the wheel was kept cool and free from overheating. This arrangement of compressor and rotor, together with the flexible joints described previously, made an easily installable outfit that has operated with remarkable success. The first supercharger of this type was mounted on a 300-hp. engine and flown for more than 50 hr. without being given the slightest attention. No failure or indication of failure of any part of the supercharger occurred. This design has been improved. The total weight has been lessened and it has been made more accessible and easy of installation. It is mounted as a unit on the engine and can be removed with the engine without interfering with other installations.

Sea-Level Pressure at Great Altitude

One interesting development in turbo-superchargers is a special outfit rated to deliver sea-level pressure at an altitude of 35,000 ft. This supercharger resembles the Form B supercharger shown in Fig. 10, but the turbine speed has been increased from 22,000 to 34,000 r.p.m. In testing the rotor and the impeller, it was given an overspeed test of 41,000 r.p.m., the peripheral velocity of the impeller at this speed being 1880 ft. per sec. or about three-fourths of the speed of an Army rifle-bullet. At this speed a 1-lb. weight having its

center of gravity located at the center of gravity of a turbine bucket would have a centrifugal force of 222,000 lb. or 111 tons. As the total weight of a bucket is only about 0.00959 lb., the centrifugal force on each bucket is 1750 lb. A great amount of experimental work was necessary to allow for this enormous force; yet, during the overspeed test, the unit stress in the buckets was less than one-half the elastic-limit of the material. However, the high temperature at which these buckets must work in actual service lowers the elastic-limit of the material and the buckets are highly stressed in such operation.

The rotor was machined from a steel forging weighing 250 lb. The finished weight is only 20 lb. or about 8 per cent of that of the original block. The turbine buckets were made of a high-chromium steel that will not scale in the presence of hot exhaust-gases. The entire weight of the supercharger is 170 lb. An idea of its capacity and efficiency is obtained by comparing it with a regular steam-driven commercial compressor

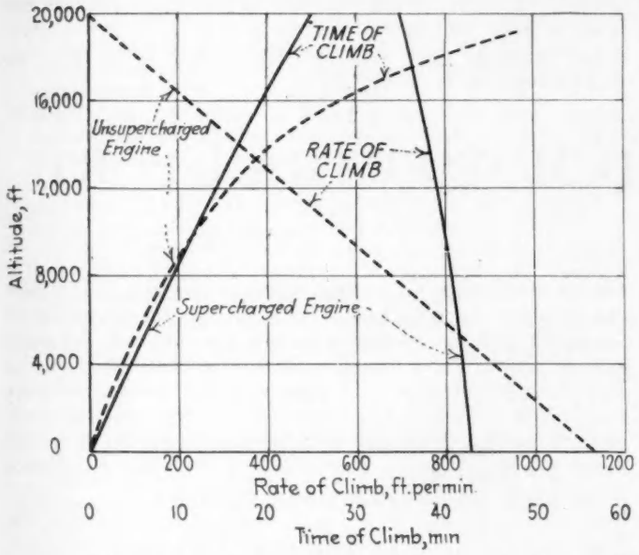

FIG. 15—RESULTS OF PERFORMANCE TESTS OF AN ORENCO D-1 AIRPLANE

This Airplane Had a Speed of 140 M.P.H. Close to the Ground and and Absolute Ceiling of 20,000 Ft. with Military Load. When Equipped with a Supercharger and a 300-Hp. Wright Engine, This Airplane Had an Indicated Altitude of Approximately 33,000 Ft. and a Speed of 146 M.P.H. At 20,000 Ft. the Unsupercharged Airplane Had a Speed of Only 90 M.P.H.

of the same capacity, which would weigh about 5000 lb. and occupy a space of approximately 6 x 8 x 6 ft. This supercharger was designed solely for experimental great-altitude work. At 35,000 ft. it increases the power of an unsupercharged Liberty engine more than 300 hp.

USEFULNESS OF THE TURBO-SUPERCHARGER

The usefulness of the turbo-supercharger can be measured best by the increase in airplane performance which resulted from its application. The first installation was made on a standard Le Pere biplane that had an absolute ceiling of 21,500 ft. and a speed at that altitude of 74 m.p.h. With a turbo-supercharger the same airplane, carrying the same load, had a ceiling of better than 35,000 ft. and a speed of 132 m.p.h. The results of flight tests of this airplane with and without the supercharger are presented in Fig. 11. During the tests on this airplane Major Schroeder and Lieutenant Elsey made a two-man world's altitude record. Later Major Schroeder made a one-man altitude record. When

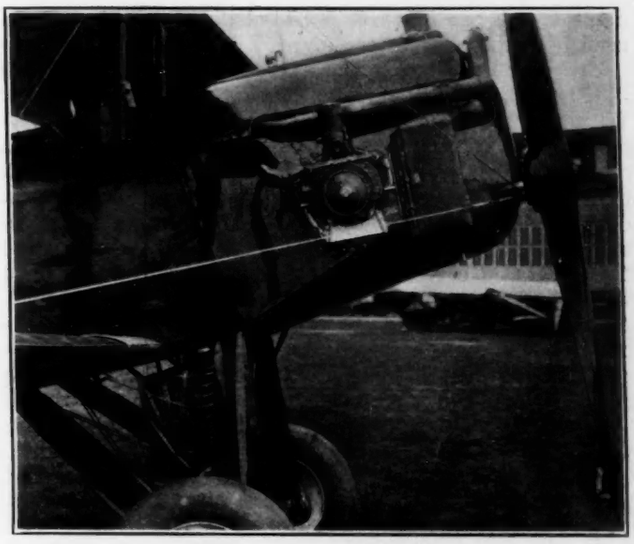

FIG. 16—A DH-4B AIRPLANE EQUIPPED WITH THE LIBERTY ENGINE SIDE-TYPE SUPERCHARGER

The Use of the Supercharger Has Increased the Service Ceiling over 50 Per Cent and the Speed at Altitude Has Been Greatly Increased

more than 30,000 ft. above the earth, his goggles became covered with frost and, when he attempted to clean them, his eyes were frozen shut by the intense cold; he became unconscious in the rarified air and the airplane fell, out of control, for 27,000 ft. When only 2000 ft. above the ground he partially regained consciousness and was able to make a safe landing. A year or more later, using the same airplane, Lieutenant Macready succeeded in breaking Major Schroeder's record. This Le Pere bi-

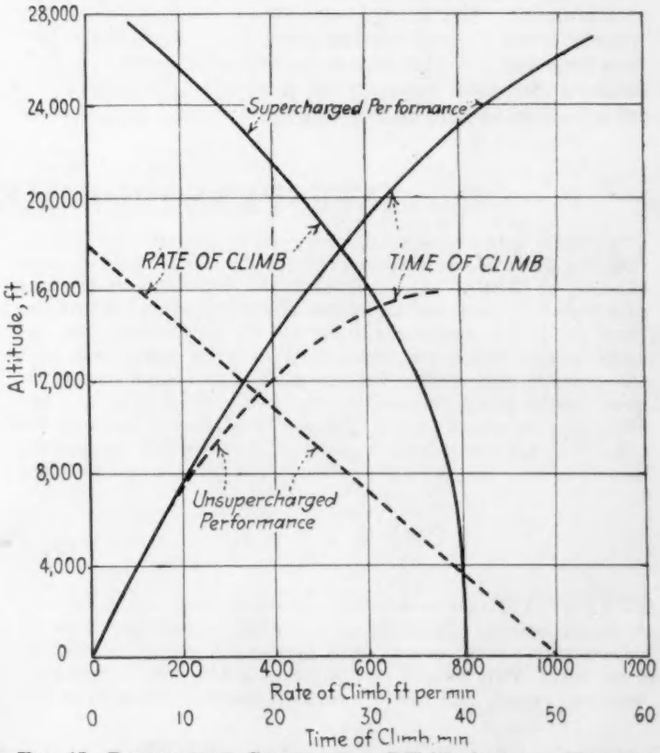

FIG. 17—PERFORMANCE CURVES OF A DH-4B AIRPLANE EQUIPPED WITH A 12-CYLINDER LIBERTY ENGINE

The Increase in the Service Ceiling Is Readily Apparent from an Inspection of the Curves for the Supercharged and the Unsupercharged Performance. The Airplane in This Case Had a Total Weight of about 4285 Lb.

plane, a veteran of three world-altitude records, is still used for supercharger testing.

The next installation, the Form-D supercharger shown in Fig. 12, was made on a Martin bombing airplane. Without military load, the absolute ceiling was more than doubled and the speed at altitude increased as is brought out by the curves reproduced in Fig. 13. After the preliminary tests had been completed, Lieutenant Wade, Captain Stevens and Roy Langham twice broke the three-man altitude record. On the second flight, when 24,000 ft. above the earth, Captain Stevens leaped overboard with a parachute and made the longest drop on record. A number of changes have been made since in the supercharger installation on the bombing plane, and a new cooling-system was designed and tested which made a great increase in its performance. During the recent bombing tests at Cape Hatteras all great-altitude flying was done by the supercharged Martin bombing airplanes, which recently carried four men and a 2500-lb. load of bombs above an altitude of 10,000 ft. With the full military load, the supercharged Martin bombing airplanes can reach an altitude of double that of the standard airplane, as is brought out in Fig. 14.

To determine the effect of the supercharger on a pursuit plane, an installation was made on the Orenco D-1. The results of a performance test are reproduced in Fig. 15. Although this was not a service airplane, it had a fairly good performance and a rate of speed of 140 m.p.h close to the ground. Its absolute ceiling with a military load was 20,000 ft. With a Form-C supercharger and the 300-hp. Wright engine, this airplane had an indicated altitude of approximately 33,000 ft. and a speed of 146 m.p.h. The unsupercharged airplane had a speed of only 90 m.p.h. at a 20,000-ft. altitude.

A number of DH-4B airplanes have been equipped with superchargers as illustrated in Fig. 16. They have been operated for 2 years. In this case the service ceiling has been increased more than 50 per cent and the speed at altitude has been increased greatly. The curves reproduced in Fig. 17 show the result of actual flight-tests better than any description can; they compare the supercharged with unsupercharged airplanes.

With better propellers even better results may be expected. At present the showing of the supercharger has been so good that now it virtually is necessary to supply a supercharger with every engine that is to be operated at altitudes above 15,000 ft.

VEHICLE BUILDER AND MOTOR TRANSPORT

(*Concluded from p.* 526)

particularly in winter. Many fleet-owners could by changing the grade of oil for their whole fleet from Nov. 1 to April 1 in certain localities add many miles per gallon to the performance of their vehicles.

Regarding drivers' seats on trucks, truck builders constantly must depend on the good temper of the driver and yet they put him on an uncomfortable seat. Simply because the steering presents a problem in angularity, no attention is paid to the sloping back and seat that all trucks should have for the driver's comfort. The seat the driver sits on should have a definite comfortable angle. I fail to see how any designer or any company can afford to have trucks driven by men who are so terribly uncomfortable. Designers and executives have been cruel in overlooking this feature, and yet they expect to get good results with men who drive 75 to 100 miles per day. From a cold business angle, I consider the drivers' comfort of primary importance.

INDISPENSABLE MEN IN GOVERNMENT

QUIET men, undemonstrative men, in all the departments of Government carry on the work. I have often thought of them in the terms of that remarkable monograph of Charles Darwin on the action of earth worms. After you have read that book you come to the conclusion that the earth worm, which you thought of only in connection with the pursuit that Izaak Walton made famous, is really the most useful of all created things. And when you have had any experience with the departments of Government in the City of Washington you come to the conclusion by and by that if it were not for the ordinary civil service grades below the rank of deputy bureau heads the Government could not go on. You will find men there, many of them college bred men, filling humble positions, doing work which by and by makes them absolutely indispensable. Department heads come and go, but they remain. In every branch of the Government will be found a certain group of indispensable men, who have been working year in and year out, receiving pitiably small returns, and yet filled with the pride of serving the Government. They would not come out and go into public employment in private life for anything.—G. W. Wickersham.

EDUCATION

INVENTIVE men laboriously reinvent what has been produced before. Ignorant men fight against the laws of nature with a vain energy and purchase their experience at great cost. Why should not all these start where their predecessors ended, and not where they began? Education can enable them to do so. The application of science to the useful arts has changed the condition and the relations of the world. It seems to me that we have been somewhat neglectful in cultivating and encouraging the scientific portion of our national economy.—Letter written in 1847 by Abbott Lawrence.

An Analysis of Costs for 10 Years of Fleet Operation

By R. E. Plimpton[1]

Metropolitan Section Paper *Illustrated with* Charts

OPERATING costs and their relation to the age of the vehicle have been a subject of controversy for some time. One faction maintains that after a certain indefinite period it is economy to salvage or junk the equipment and replace the vehicles with later uptodate designs. The opposing faction believes that the costs depending on maintenance and operating efficiency can be kept fairly constant. Comparing a motor truck with a locomotive they cite the opinion of railroad officials that when proper running repairs are made locomotives can be maintained continuously in the same service and retain their original earning capacity for many years. When new locomotives are built it is usually for the purpose of replacing types that have become obsolete and the old ones are then relegated to some other branch of the service.

Replying to those who maintain that costs rise with age they assert that the motor vehicle is not designed never to wear out; that its maintenance facilities are not comparable with those of a railroad; that each successive overhaul increases in cost because parts either increase in cost or cannot be bought at all and have to be made to order. The question, in the opinion of the author, resolves itself into the case of the vehicle itself: whether it has reached the point where basic improvements are no longer probable and whether first costs will become lower because of greater production.

The most notable development within the last 10 years has been in the price, which is now about the same as it was 10 years ago, notwithstanding the increase in the cost of parts; the weight is about the same and changes in construction have been slight; performance and fuel consumption are also about the same. Maintenance, on the other hand, aided by better inspection, better adjustment and better overhauling, has improved greatly. Based on an accounting system adapted from railroad practice, the cost-keeping methods of the motorbus companies give them a great advantage.

The three factors that may lead to the replacement or the renewal of a complete vehicle are (*a*) physical depreciation, (*b*) obsolescence and (*c*) inadequacy, each of which is discussed. Adequacy is important in order that the type of equipment demanded by the public may be provided. In general, methods of valuation adopted by the regulatory bodies with regard to railroads are applied to motor common-carriers. As an illustration, the course pursued for determining the proper rate of fare-increase to be allowed a motorbus company in Albany is cited.

Graphical charts are given showing the results of double-deck motorbus operation by the Fifth Avenue Coach Co., but these are slightly modified by including taxes. Other charts show the variation of operating costs of 2 and 5-ton gasoline trucks, heavy-duty trucks and 2-ton electric trucks. The yearly variations since 1914 in the costs of gasoline and tires as compared with the wholesale commodity-price index, and those of finished steel as compared with the ratio of the average list price of 5-ton truck parts, are also illustrated by graphs.

[1] M.S.A.E.—Associate editor, *Bus Transportation*, New York City.

WHAT happens to operating costs as a motor vehicle grows older? Does the expense for repairs, for labor and materials, keep growing larger as Father Time rolls on his motor-propelled way? And the amounts paid out for fuel, tires and similar more or less quickly consumed supplies, do these increase year by year? To get intelligent answers to these questions, resort must be had to fleet operators of motor trucks or motorbuses. They are the only ones who know the costs and who have kept them long enough, under uniform conditions of maintenance and operation, to permit sound judgment as to the variation from year to year.

Later in this paper some of these costs are summarized, to show what happens after similar vehicles have been in service for a considerable period. But before presenting these figures, it should be said at once that opinions differ widely among fleet operators; some hold that, after a certain rather indefinite time, it is economy to salvage or junk old equipment and replace the vehicles with later and uptodate designs. Others believe, and just as strongly, that the costs depending on maintenance and the operating efficiency can be kept fairly constant. Some members of the second group even go so far as to say that with proper attention the present motor-vehicle "can be run indefinitely and with a profitable net result to the owner." These two points of view have been discussed recently with both the

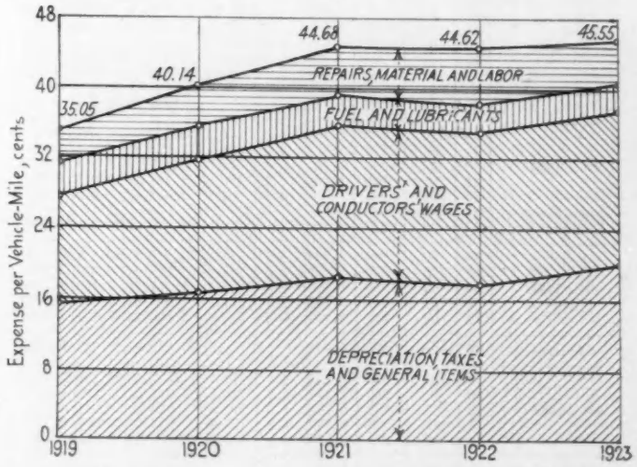

Fig. 1—Operating Expense for Double-Deck Buses in Cents per Vehicle-Mile from June 30, 1919 to June 30, 1923

Year	Revenue Miles	Repairs	Fuel and Lubricant	Platform Labor	Depreciation, Taxes and General Items	Total
1919	8,087,127	3.51	4.11	12.03	15.40	35.05
1920	8,796,195	4.35	3.92	15.10	16.77	40.14
1921	9,191,825	5.19	3.94	16.96	18.59	44.68
1922	9,683,500	6.21	3.51	17.17	17.73	44.62
1923	10,019,805	4.81	3.26	17.44	20.04	45.55

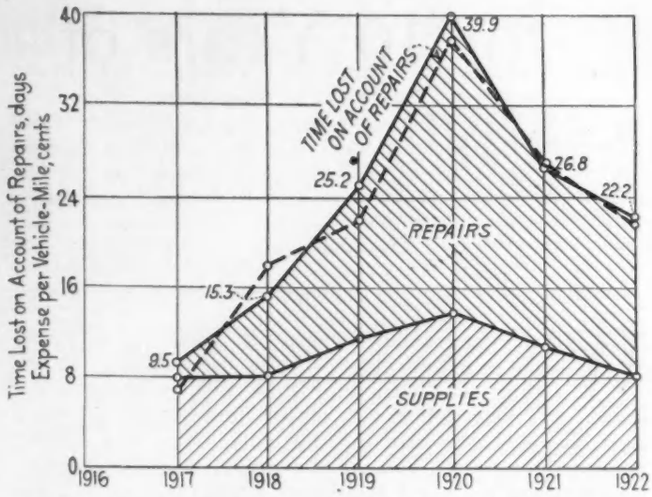

FIG. 2—MAINTENANCE EXPENSE FOR 2-TON GASOLINE TRUCKS

Year	Performance: Days Idle: In Repair	Performance: Days Idle: Other	Performance: Days in Use	Performance: Yearly Mileage	Gasoline, Miles per Gal.	Lubricant, Miles per Gal.	Total Repair Cost	Repair Cost per Mile	Total Operating Expense per Mile
Feb. 14, 1916	4	66	252	6,782	4.8	169.6	$55.32	$0.008	.....
Feb. 19, 1916	....	55	262	7,805	5.0	168.3	67.69	.009	.....
Feb. 19, 1916	....	55	262	3,497	3.8	103.6	20.73	0.006	.....
March 1, 1916	....	58	248	5,543	5.2	188.7	10.35	0.002	.....
Average	....	72	256	5,906	.....	.....	$38.52	$0.006	.....
1917	37	63	265	6,693	3.8	150.4	$246.02	$0.037	$0.153
	1	65	299	10,381	5.4	143.9	99.13	0.010	.....
	....	64	301	6,828	3.9	155.6	93.61	0.014	0.132
	....	70	295	6,711	4.8	179.0	36.54	0.005	0.093
Feb. 26, 1917	....	50	259	7,319	3.4	145.7	81.99	0.011	0.101
Average	7	62	283	7,586	.....	.....	$111.45	$0.015	$0.095
1918	27	64	274	6,276	3.8	83.8	$567.04	$0.090	$0.217
	2	56	307	9,275	4.8	108.6	73.21	0.008	.....
	38	58	269	7,617	4.1	137.9	1,225.38	0.161	0.274
	....	64	301	5,700	4.8	168.9	26.70	0.005	0.097
	26	75	264	9,182	4.3	108.8	888.76	0.097	0.181
Average	18	63	283	7,610	.....	.....	$556.21	$0.072	$0.153
1919	22	66	277	6,343	4.2	114.5	$738.68	$0.116	$0.233
	44	49	272	6,399	4.2	157.0	1,605.59	0.235	0.365
	3	59	303	7,033	4.8	111.2	143.37	0.020	0.123
	28	55	282	5,394	4.7	172.6	1,077.79	0.200	0.279
	17	82	266	6,893	3.7	144.6	1,013.65	0.114	0.262
Average	22	62	280	6,792	.....	.....	$895.81	$0.137	$0.252
1920	48	110	208	5,141	4.0	141.8	$2,153.54	$0.418	$0.551
	34	56	275	7,273	4.0	181.8	1,222.29	0.168	0.302
	50	58	258	6,051	4.8	74.0	2,120.72	0.350	0.465
	25	61	280	5,460	4.4	156.6	1,156.30	0.212	0.350
	36	66	264	8,359	3.6	60.5	1,444.44	0.173	0.327
Average	38	70	257	6,456	.....	.....	$1,619.45	$0.260	$0.399
1921	39	66	260	7,394	4.1	143.2	$1,240.31	$0.168	$0.271
	43	65	257	6,259	3.8	195.6	1,378.21	0.220	0.340
	36	60	269	6,563	4.9	84.4	1,267.76	0.193	0.306
	7	67	291	4,905	4.1	74.2	524.61	0.107	0.207
	12	62	291	9,723	3.8	212.2	1,084.25	0.112	0.219
Average	27	65	273	6,969	.....	.....	$1,119.02	$0.160	$0.268
1922	15	100	250	4,893	4.5	171.7	$637.28	$0.130	$0.238
	50	56	259	7,170	4.7	116.8	1,371.55	0.191	0.299
	3	65	297	6,704	4.7	191.5	273.83	0.041	0.113
	4	52	299	5,589	3.8	101.8	143.97	0.026	0.128
	39	55	271	9,578	3.8	120.5	2,023.59	0.211	0.335
Average	22	67	275	6,786	.....	.....	$890.04	$0.119	$0.222

rising-cost and constant-cost contingents still on their feet and seemingly able to take more punishment.

THE CASE FOR CONSTANT COSTS

In considering the opinion that operating costs can be kept uniform or fairly constant, it is instructive to turn for a moment to steam railroad practice. Here the locomotive can be compared, to a certain extent at least, with the chassis of a motor truck or motorbus. The general opinion among railroad operating officials is that, when proper running repairs are made, locomotives can be maintained continuously in the same service; and it is often held that they retain their full original earning capacities during this period, that is, continuously. Right from the beginning, when the locomotive is designed, the builder aims to obtain such a piece of equipment that periodic repairs will maintain it at its original efficiency.

But new locomotives are being built and used to replace other types thereby made obsolete. The old equipment is not retired because it is worn out, however, but because service conditions have changed so that a different kind of rolling stock is considered to be more economical.[2]

IN FAVOR OF RISING COSTS

How far can we go in using these results of long years of locomotive development? The upholders of the rising-cost principle may say that it has no application to motor-vehicle operation; that the motor vehicle, even when new, is not designed never to wear out, as is the locomotive, nor are the maintenance facilities at all comparable to those available at the shops where the rail motive power gets its complete overhaul. Present motor-vehicle designs, they claim, cost more and more as they grow older. Not only is each successive overhaul more expensive, but routine repairs between overhauls also cost more as time goes on. Breakages are more frequent due to crystallization. Parts are more expensive to buy as the truck gets older, or they cannot be bought at all and must be made to order, a slow and expensive process. These represent the arguments advanced.

It will be seen that both the pro and the con sides of the question of costs and their variations bring us back to one thing: the vehicle itself; also to another question: Has the art of motor-truck construction reached a level where basic improvements are improbable and the future will show merely refinements to permit easier maintenance, or will first costs become lower because of production in larger numbers?

HOW MUCH ARE TRUCKS IMPROVING?

A general feeling prevails that motor vehicles are getting better, year by year. This is natural. We always hope for progress and for fundamental improvements, even though the advance may be only in details. But it is difficult to define basic improvements, say in the last 10 years.

Probably the most notable development has been in the price. In dollars the selling price of a 2½-ton truck is about the same now as it was 10 years ago, in spite of the fact that prices have gone up about 50 per cent.

Weight is nearly the same, 4000 or 5000 lb. Changes in construction have been comparatively slight. The worm drive and the disc clutch have come in, with some increase in four-speed gear-shifts and block-type engine-cylinders. The composite truck of 2½ tons capacity for 1914, according to the first-of-the-year issue of *The Automobile*, had a 4⅛ x 5¼-in. engine, pump cooling, magneto ignition, 36 x 4-in. solid tires on the front wheels, 36 x 3½-in. dual tires on the rear wheels, with the final drive by chain. Not much difference here. And the article describing the composite design concludes with a statement that starters and batteries are regarded as of doubtful value, except on light delivery wagons. This statement requires no comment.

[2] See *Engineering*, Nov. 16, 1923, p. 609.

Ten years ago a performance of 7 to 9 miles per gal., or 45 to 60 ton-miles per gal., was considered good for 2 to 3-ton trucks. Not much better work is being done by vehicles of that size today, although the gasoline consumption is about the same. At least, the tests of the Bureau of Standards have not shown that the fuel economy improves as the fuels decrease in volatility, the main change in the last 10 years.

Has Maintenance Practice Improved?

Assuming that vehicle construction has not gone ahead to any great extent as regards fundamentals, what about maintenance? Undoubtedly, this has developed. During the last decade the great garage organizations back of our fleets of commercial motor-trucks have been brought together and by hard experience have learned many valuable lessons. Especially since the war they have settled down, and a policy of inspection, adjustment and overhauling has been adopted. Systems and records have been worked out so that comprehensive operating figures, gathered under fairly comparable conditions, are available. Factory production methods are not here yet, except in a few service-stations where special jigs and fixtures are used in making repairs.

It is believed that the standard of management to which we can look forward in the future has not yet been reached. Technically minded men are taking over supervisory functions in fleet operation more and more; but the highest duty of management, using the past to guide the future, can and should be displayed to a much greater extent in fleet operation. In this respect motor-bus operating companies that work with a transportation accounting system adapted from railroad practice have a great advantage. Their course is charted to a considerable degree because standards of comparison are thoroughly known.

Time to Retire

Aside from purely commercial considerations, such as an unusually good offer to trade-in an old truck, three factors may lead to the replacement or the renewal of a complete vehicle. First is physical depreciation, including accidents, but ordinarily relating to wear and tear that may be largely compensated for by charges for repairs. We must consider whether the modern motor-vehicle wears out like the famous "one-hoss shay," until good for nothing except scrap metal. Is it to be renewed in parts or important units, or as is a railroad, by perpetual reproduction?

Obsolescence, the second factor, is the result of changed conditions outside the vehicle considered, which makes it cease to be useful or profitable. Improvements in the art of construction might lead to obsolescence.

Speaking in insurance terms, the life expectancy of the mechanical device we are analyzing depends primarily on the factor of obsolescence. If improved equipment comes on the market, what is the use of keeping on with inferior types? Why bother to renew important units and make the job as good as new with each overhaul?

The life expectancy of locomotives increases year by year. Those turned out recently can be expected to hold a place for a longer total time than that of their predecessors, and those to be built in the near future will doubtless do even better. Behind this change, of course, is the fact that improvements of a radical nature are no longer being made. Refinements there may be in plenty, but often these can be applied to existing rolling-stock. And it may be cheaper to do this than to buy new equipment.

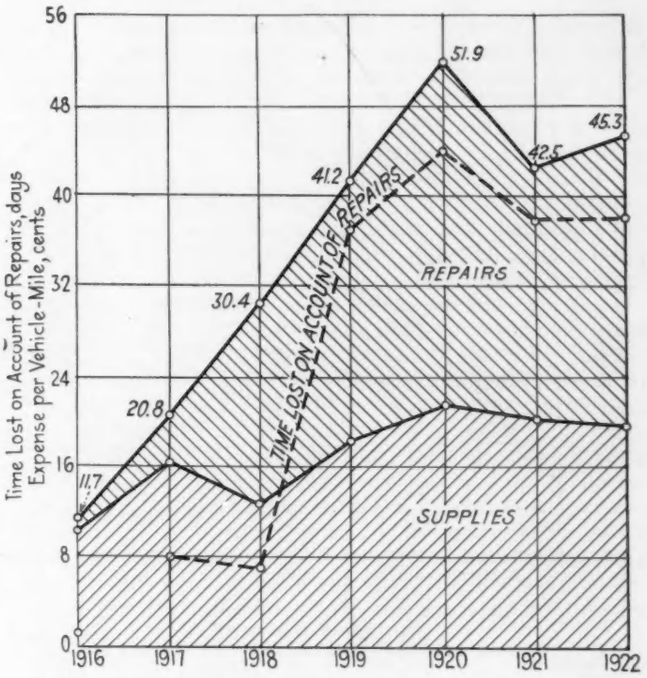

Fig. 3—Maintenance Expense for 5-Ton Gasoline Trucks

Year	Performance: Days Idle, In Repair	Performance: Days Idle, Other	Performance: Days in Use	Performance: Yearly Mileage	Gasoline, Miles per Gal.	Lubricant, Miles per Gal.	Total Repair Cost	Repair Cost per Mile	Total Operating Expense per Mile
July 8, 1916	1	31	145	3,081	1.8	148.5	$81.80	$0.027	$0.175
June 17, 1916	3	32	165	6,072	2.6	264.0	93.92	0.015	0.116
July 11, 1916	....	29	145	4,183	3.3	363.7	27.83	0.007	0.090
June 26, 1916	.....	33	162	4,854	2.7	211.0	31.45	0.006	0.107
June 26, 1916	3	33	153	6,191	3.2	289.6	80.08	0.013	0.098
Average	1	32	153	4,876	.....	.....	$63.01	$0.013	$0.117
1917	....	66	299	8,299	2.5	197.6	$152.61	$0.018	$0.144
	5	48	312	10,210	2.2	140.8	133.39	0.013	0.204
	2	64	299	10,215	3.4	216.2	158.52	0.016	0.154
	10	63	292	6,782	2.2	204.0	343.88	0.051	0.206
	21	58	286	9,883	2.5	159.7	1,232.53	0.125	0.333
Average	8	60	297	9,078	.....	.....	$404.18	$0.044	$0.208
1918	2	70	293	8,110	2.7	176.3	$228.56	$0.028	$0.162
	47	42	276	10,038	2.5	177.7	1,716.04	0.171	0.394
	64	52	249	7,837	3.0	206.2	1,465.66	0.187	0.328
	44	60	261	5,442	2.0	103.9	1,277.83	0.235	0.425
	8	60	297	9,464	2.8	329.2	555.81	0.059	0.233
Average	7	56	275	8,178	.....	.....	$1,048.78	$0.176	$0.304
1919	47	59	259	4,365	2.0	67.5	$1,641.27	$0.376	$0.625
	49	50	266	8,220	2.9	166.9	1,843.91	0.224	0.368
	....	59	306	6,927	3.1	167.9	206.67	0.030	0.163
	30	70	265	8,070	3.1	135.9	1,649.68	0.204	0.398
	59	54	252	6,562	2.9	150.4	2,037.46	0.310	0.506
Average	37	58	269	6,829	.....	.....	$1,475.80	$0.229	$0.412
1920	30	68	268	4,346	1.8	108.3	$2,056.54	$0.473	$0.861
	59	42	265	8,619	3.0	134.4	2,888.59	0.335	0.559
	37	61	268	6,210	2.9	143.6	1,968.99	0.317	0.498
	14	68	284	9,062	3.2	242.2	746.03	0.082	0.251
	80	48	238	11,136	3.2	124.4	2,368.89	0.303	0.445
Average	44	57	265	7,874	.....	.....	$2,205.80	$0.302	$0.519
1921	4	64	297	4,450	1.5	105.3	$642.54	$0.144	$0.458
	58	55	252	8,218	3.3	342.4	2,303.94	0.280	0.456
	40	60	265	5,910	3.1	99.1	1,665.66	0.282	0.431
	51	56	258	9,380	3.5	295.4	2,372.71	0.253	0.404
	38	60	267	9,337	3.2	217.8	1,378.11	0.148	0.380
Average	38	59	268	7,459	.....	.....	$1,672.55	$0.221	$0.425
1922	47	56	262	6,093	2.3	123.3	$1,603.35	$0.263	$0.498
	24	58	283	8,339	2.8	193.0	1,719.54	0.206	0.373
	32	59	274	4,381	2.3	87.5	921.71	0.210	0.433
	34	60	271	4,977	1.8	101.8	1,930.17	0.388	0.622
	34	59	252	7,310	2.8	183.1	1,542.67	0.211	0.350
Average	38	58	268	6,220	.....	.....	$1,543.49	$0.255	$0.453

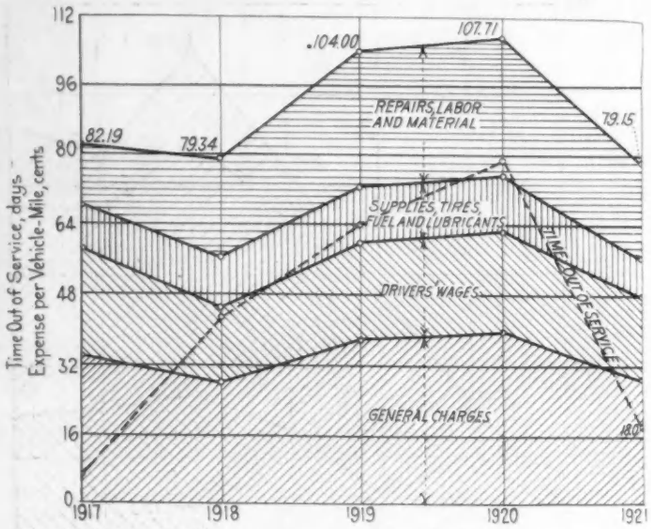

FIG. 4—OPERATING EXPENSE FOR HEAVY-DUTY TRUCKS USED IN PIER WORK FROM DEC. 31, 1917 TO DEC. 31, 1921

Year	1917	1918	1919	1920	1921
Operating Expenses					
Fixed Charges	$2,824.80	$3,124.56	$2,824.80	$2,913.60	$2,935.20
Gasoline	735.73	940.00	850.00	764.84	680.20
Oil	63.13	84.00	73.00	68.00	78.00
Tires	30.00	102.00	65.00	140.00	116.67
Body Repairs	92.89	55.69	135.00	194.86	30.40
Chassis Repairs	14.87	37.40	108.40	48.20	167.40
Driver's Wages	1,991.57	1,756.00	1,625.35	1,710.80	1,835.20
Inspector's Wages	1,040.00	2,080.00	2,080.00	2,080.00	2,080.00
Total Operating Cost	$6,792.99	$8,179.65	$7,761.55	$7,920.30	$7,923.07
Performance and Unit Cost					
Days Operated	298	261	240	225	286
Miles Covered	8,264	10,280	7,440	7,340	10,010
Tons Hauled	3,579	3,393	2,880	2,227	2,574
Cost per Day	$20.414	$25.657	$25.339	$26.681	$23.907
Cost per Ton Hauled	1.899	2.410	2.695	3.556	3.078
Operating Expenses, Cents per Vehicle-Mile					
Repairs, Material and Labor	13.89	21.13	31.22	31.65	22.76
Supplies, Tires, Fuel and Lubricant	10.03	10.92	13.24	13.23	8.74
Driver's Wages	24.09	16.98	21.69	23.21	18.33
Fixed Charges	34.18	30.31	37.85	39.62	29.32
Total	82.19	79.34	104.00	107.71	79.15

Inadequacy, the third factor, means a loss of value or service life, because of a change in working conditions. The vehicle can no longer do the work required of it and gives way to something more suitable. It follows that with replacements due to obsolescence or inadequacy, the vehicles might still be useful under different operating conditions.

Motor common-carriers, either of goods or of passengers, are more liable to be affected adversely by inadequacy than are privately-operated vehicles. The motorbus or motor truck, following a given route and holding itself out to serve anyone at a uniform price, must provide equipment of the type demanded by the public, or a falling off of patronage and financial disaster will be the penalty. Being limited, in many States at least, to a just and reasonable return upon the valuation of the property in use, these operators have particular reason to analyze the life expectancies and the methods of valuation followed by regulatory authorities.

So far the commission has followed the relatively simple methods used by private fleet operators. An inclination is noticed, however, to apply the principles developed in railroad valuations, particularly if the same commission also handles motor-vehicle, or common-carrier, regulation.

An example of the possibilities is afforded by a case before the Public Service Commission of the State of New York 2 years ago. An operator working 13 motorbuses in the City of Albany applied for a fare increase. He got it, but not so much as he asked for, the Commission splitting the difference with him and permitting him to increase his fare from 6 cents to 7. But the point of interest was the method followed in determining the maximum fare that would give the operator reasonable compensation.

The valuation of the property was made on the basis of the first cost of the motorbuses and garage tools, from which was subtracted a depreciation reserve, and to which was added a working capital of $2,000. This amount consisted of $1,000 for cash capital and $1,000 for use in buying supplies. On the valuation, about $58,000, the operator was entitled to a return of 8 per cent after meeting operating costs. The fare itself was calculated on the assumption that 145,000 passengers would be carried per month and this, in turn, was based on the business done during certain winter months.

Depreciation according to three different methods was discussed in the opinion of the Commission. The builder of the motorbuses figured it on a mileage basis. The motorbus company had previously estimated the useful life to be 5 years, and had charged off 25 per cent the first year, 20 per cent for each of the next 3 years and **15 per cent for the fifth and last year.** Finally, the Commission stepped in and established a yearly depreciation of 20 per cent with an allowance of $500 per motorbus for salvage, as "more suitable than the decreasing percentage used by the company." And after all this, the Commission held that it was the duty of the petitioner, the motorbus company, to give attention to the care of

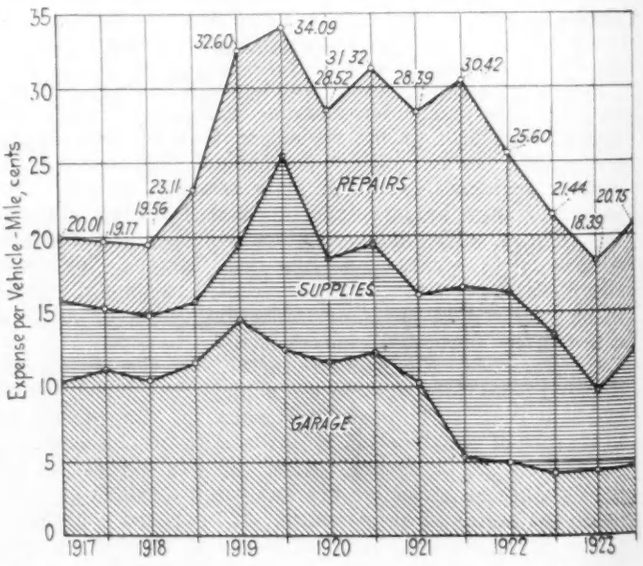

FIG. 5—MAINTENANCE COST OF FLEET OF 1 TO 5-TON ELECTRIC TRUCKS FROM MARCH 1, 1917 TO DEC. 31, 1923 IN CENTS PER VEHICLE-MILE

Period Ended	Garage	Supplies	Repairs	Total
June 30, 1917	10.33	5.58	4.10	20.01
Dec. 31, 1917	11.16	4.12	4.49	19.77
June 30, 1918	10.45	4.37	4.74	19.56
Dec. 31, 1918	11.69	4.18	7.24	23.11
June 30, 1919	14.50	5.03	13.07	32.60
Dec. 31, 1919	12.48	12.94	8.67	34.09
June 30, 1920	11.61	6.97	9.94	28.52
Dec. 31, 1920	12.25	7.35	11.72	31.32
June 30, 1921	10.26	5.91	12.22	28.39
Dec. 31, 1921	5.32	11.29	13.81	30.42
June 30, 1922	5.00	11.36	9.24	25.60
Dec. 31, 1922	4.29	9.13	8.02	21.44
June 30, 1923	4.37	5.37	8.65	18.39
Dec. 31, 1923	4.69	7.85	8.21	20.75

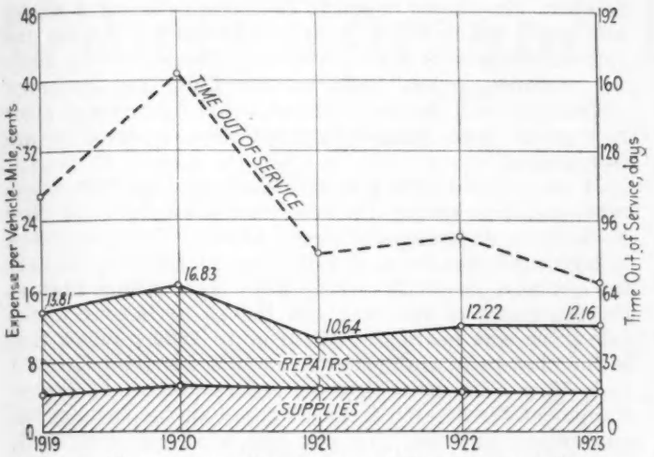

FIG. 6—MAINTENANCE EXPENSE FOR 2-TON ELECTRIC TRUCKS

Year	1919	1920	1921	1922	1923
Tires	$70.00	$149.75	$284.54	$254.92	$287.27
Mechanical Department Labor	155.35	493.76	113.76	38.33	27.70
Mechanical Department Material	315.05	354.83	250.81	575.50	214.40
Electrical Mechanics [2]	420.29	1,229.30	1,601.08	1,537.06	1,526.20
Body Department Labor	.....	214.90	171.50	350.73	935.18
Body Department Material	.....	20.03	34.79	53.75	118.90
Electric Current	328.78	899.39	1,581.04	1,344.36	1,549.04
Total	$1,289.49	$3,361.96	$4,037.52	$4,154.65	$4,658.69
Days in Service	395	1,207	1,858	1,794	1,956
Mileage	9,333	19,967	37,938	33,990	38,303
Repair Cost, cents per mile	4.27	5.25	4.92	4.71	4.79
Total Cost, cents per mile	13.81	16.83	10.64	12.22	12.16

[2] This item covers the time of the mechanics engaged in inspection, battery charging, minor repairs and adjustments.

the buses and to prevent increased cost of repairs by attending to lubrication and making repairs at once when needed.

COMPARISON OF COSTS

The figures that accompany this paper relate to operation in and around New York City within the last 10 years. Unit costs are figured on a considerable number of similar vehicles, gasoline and electric, used under comparable conditions of service by public utilities, department stores and haulage companies, among others. For a given group of vehicles, a picture is presented, therefore, of the important items of expense for a definite time. It is not expected that the costs of any one group will bear any relation to those of another and, in fact, in the absence of more complete information, it would be foolish to attempt any such comparison.

Figures have been collected from different sources, including public utility companies, department stores, haulage companies and the like, all of which operate large fleets; they are presented so that the operating costs can be compared from year to year. It would not be fair, or useful, to compare the costs that I show with your own, because the conditions are not at all alike, and because of the way in which the figures have been collected. I cannot give you as much information as I should like, for many of the persons who gave the figures to me did so on condition that the sources should be kept confidential.

Nothing is confidential about the figures shown in Fig. 1, because if you go to the Transit Commission on Lafayette Street, New York City, you can get them yourself. They are on record there as the results of operation of the Fifth Avenue Coach Co. The totals, however, will be slightly different from the figures given out by the Transit Commission because I have included taxes. They should be included in the general expense, which is given in the lower strip, although, as a usual thing in transportation, operating costs and taxes are listed separately.

I have followed a form here that I shall use later; I began at the bottom with general expense, then labor, when I happened to have it, then supplies, which in this case include fuel and lubricants, and finally, at the top, repairs; that is, materials and labor, on both chassis and body, as this item happens to be. That is done to bring up at the time when they are most prominent the items that are most closely related to the vehicle.

From 1919 to 1923 more than 270 buses operated in the fleet at all times; in the fiscal year, 1923, the number varied from about 270 to 293 or 296 revenue buses. In the first 3 years the figures increase rapidly to 35 cents per vehicle-mile, or per motorbus-mile, then to 44 cents, then to 45 cents. Just how much that increase is due to new equipment with larger seating-capacity, I do not know. If we were able to figure it out on a seat-mile basis, the curve would probably be much more nearly flat, although during the last 5 years the equipment has been fairly well standardized until the last year or two, when Type L buses came into use, and also some double-deckers, which affect the averages.

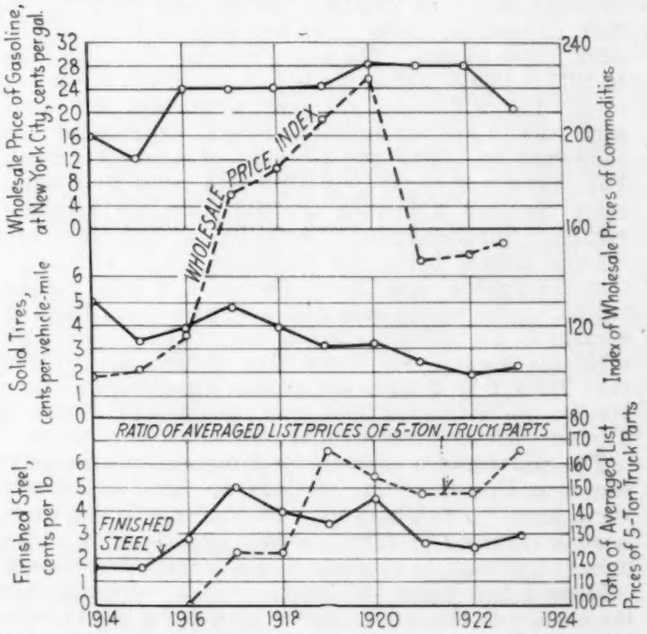
Wholesale Price of Gasoline, at New York City, cents per gal.
WHOLESALE PRICE INDEX
Index of Wholesale Prices of Commodities
Solid Tires, cents per vehicle-mile
RATIO OF AVERAGED LIST PRICES OF 5-TON TRUCK PARTS
Finished Steel, cents per lb
FINISHED STEEL
Ratio of Averaged List Prices of 5-Ton Truck Parts
1914
1916
1918
1920
1922
1924

FIG. 7—BUSINESS FACTORS AFFECTING FLEET OPERATION FOR THE 10 YEARS, 1914-1923

Year	Gasoline, Cents per Gal. [3]	Solid Tires, Cents per Vehicle-Mile [4]	Bar and Sheet Steel Cents per Lb. [5]	Ratio of List Prices of 5-Ton Truck Parts [6]	Price Index of Wholesale Commodities [7]
1914	16.0	5.028	1.52	...	98
1915	12.0	3.372	1.62	...	101
1916	24.0	3.876	2.86	100	127
1917	24.0	4.722	5.01	122	174
1918	24.0	3.948	3.94	122	186
1919	24.5	3.012	3.47	165	207
1920	28.5	3.138	4.53	154	225
1921	28.0	2.424	2.69	148	147
1922	28.0	1.944	2.46	148	149
1923	20.5	2.166	3.05	166	154

[3] Tank wagon prices in New York City. Compiled by Bureau of Mines, except for 1923, which was average of monthly figures from *Bus Transportation*.

[4] Based on cost of six 36 x 5 solid tires and a mileage life of from 6000 to 9000.

[5] Average of yearly prices from *The Iron Age* for bar steel and black sheets.

[6] Based on the sum of the list prices of 11 typical metal parts for 5-ton truck.

[7] Average of monthly values worked out by United States Bureau of Labor Statistics.

Fig. 2 shows the figures for 2-ton gasoline trucks. Something rather interesting is the way that the curve for "time out on account of repairs" follows the cost. That relation does not seem to hold in any other curve, however. The totals dropped considerably in 1922, and the supplies also. A peak occurred in 1922; after that all expenses fall off.

In Fig. 3 is shown an installation where a power take-off was used to a great extent. The 1921 total costs show no irregularity; they seem to jump up afterward, although the cost of supplies dropped.

Figures taken from a fleet of 12 5-ton trucks used in pier work around New York City are shown in Fig. 4. The dotted curve is slightly different from the one shown in Figs. 2 and 3 in that it represents time out of service. It drops off to 18 days in 1921. Time out of service includes not only the days lost because of repairs but also those lost because of lack of business. In 1920 they evidently had a bad season; it is very high. This is a Fifth Avenue Coach Co. curve. I was able to show the general charges, drivers' wages, supplies, tires, fuel, lubricants, and finally, at the top, labor, repairs and material.

The figures shown in Fig. 5 were given to me through the courtesy of E. E. La Schum. They are a compilation of the monthly figures since 1917 for one fleet of electric trucks that he operates from his big 42nd Street garage. The number varied from about 200 in 1917 to 260 or 270 at the latter part of the period covered. You will notice that two points are plotted for each year. I had the figures by months but reduced them somewhat by taking the averages of 6-month periods. For instance, directly over 1918 is a point that represents the first 6 months of 1918, then the second 6 months. Supplies include electricity, oil and tires; and repairs include labor and materials. You will notice that the caption says "For a fleet of 1 to 5-ton electric trucks." The vehicle-mile does not mean much there on account of the difference in the size of the vehicles; but after checking-up we found that though the vehicles vary from 1 to 5 tons, the greater number were 2-ton trucks; we estimated that they would approximate a 2½-ton vehicle, if any such electric truck were made.

The maintenance expense for 2-ton electric trucks is shown in Fig. 6. Some of these are used in delivery work, some in freight work. The mileage is not high. A peak occurred in 1920, possibly because of the high prices of mileage in general; then the curve dropped off.

When I first began this study, it occurred to me that the change in the buying power of a dollar might have a great influence on costs, as we compare them from year to year. So when I began to calculate by using a wholesale-price commodities index, which seemed to me the fairest thing as a start at least, I found that in 1920, for instance, prices were so low that they appeared ridiculous; so I decided to take actual figures and show how prices have changed over the 10-year period we are considering.

If we begin at the top of Fig. 7, the full line represents gasoline prices, the wholesale-price index in New York City. It begins at 16 cents, drops a little, and then is high until last year. The figures for the last year are the average, about 20 cents. They were rather high at the beginning of the year and the 15 to 16-cent wholesale price was heard of just prior to 1923. Below that is the change in cost per vehicle-mile for solid tires. I took 36 x 5-in. solid tires as representative of typical equipment for 3½-ton trucks, figured on the basis of the guaranteed mileage; you can see what has happened; they fluctuate a little at the beginning and gradually drop until 1922, when the increase is very marked. At the bottom is the curve for finished steel. I wanted to get something that would show the variation in the costs and prices of parts we have to buy. I went to *The Iron Age* and found a so-called composite price of finished steel, but that included so many factors that do not enter into the automobile at all, I thought it best not to use it; so, instead, I took two factors, bar steel and black sheets, which I understand represent about 75 per cent of the steel used in the automobile industry, and plotted them.

These parts are practically standard and, while they represent the list price, I think the comparison is fair for 1916. You see, 1916 is plotted as 100; the dotted line, marked "List prices of 5-ton truck parts," goes up to about 165 in 1923, with a peak in 1919. It does not seem to have much relation to any of the other curves.

Some of the important variables have been eliminated by the method of using averages; for example, costs that might appear unduly high if only one vehicle were considered. But no attempt to eliminate the fluctuation in the worth of commodities has been made. Instead a separate table is shown to represent the change in the value of the dollar. The index for wholesale prices of commodities, as figured by the United States Bureau of Labor Statistics, was down to 97 early in 1914, reached a peak of 247 in May, 1920, and fell off to 138 in January, 1922, after which it rose again to 154 in December of last year. Important supplies used in fleet operation did not follow these index prices exactly, but the current quotations for gasoline and steel products, and an estimated cost of rubber tires are given for purposes of comparison.

SYDNEY BERTRAND AUSTIN

ANNOUNCEMENT of the death, March 3, 1924, of Sydney Bertrand Austin, factory manager for the Kny-Sheerer Corporation of America, New York City, was made by his widow. He was born March 1, 1874, at the City of Washington, and was 50 years of age. Following his preliminary education, he attended Johns Hopkins University from 1891 to 1893; then entering Cornell University, he was graduated in 1895 and received the degree of mechanical engineer.

Mr. Austin was in entire charge of the mechanical design of the Rowland multiplex printing telegraph at Baltimore from 1903 to 1906. He then practiced consulting engineering in that city, on his own account, until 1915. Then becoming tool and maintenance engineer for the Poole Engineering & Machine Co., he continued this service until April, 1917, when he entered the United States Navy. He was ordnance and gunnery officer until June, 1918; assistant inspector of ordnance in charge of fire control apparatus until October, 1918; and a demobilization officer at New York City until Nov. 1, 1919. From Sept. 21, 1918, he ranked as a lieutenant-commander. Entering the engineering department of the Eisemann Magneto Corporation, Brooklyn, N. Y., in November, 1919, he became its inspection engineer. Later, he formed a connection with the Kny-Sheerer Corporation. He specialized in gages, tooling and manufacturing methods. He was elected to Member grade in the Society, Sept. 25, 1920.

Quiet Gears and Their Production

AT the first monthly production meeting of the Detroit Section on Nov. 15, 1923, a symposium was held regarding the advantages of the various production methods that had been adopted by several of the leading automobile companies for reducing the noise of gears and the results that had been obtained by the use of these methods. To this round-table discussion papers were contributed by W. R. Griswold, O. H. Schafer, L. A. Danse, R. E. Linn, W. G. Hildorf and A. H. Frauenthal. Each one of these papers is printed in full and a number of the lantern slides that were shown at the meeting have been reproduced to illustrate more clearly the points brought out in the text of the different papers presented.

SOME SIDELIGHTS ON THE GEAR PROBLEM

BY W. R. GRISWOLD[1]

ALTHOUGH the sliding-gear transmission did not fulfil the expectations of its creator it has withstood the onslaughts of inventive genius in the effort to replace it. But recently efforts have been renewed to produce smoother and more quietly running gears, partly because of the demands of the public, partly because of the use of higher engine speeds and closed bodies. The author, after discussing the nature of sound and the causes of noise, investigates the sources of vibration in transmissions to which most noises were found to be due.

Vibrations are set-up in a body when it is subjected to change of shape; possessing inertia and being elastic, the body tends to return to its original shape when the pressure is removed and waves of stress are set-up. These become sound waves when their frequency or wave lengths come within the range of hearing. They may be set-up by the direct impact of bodies, by rubbing or by changing any applied loads or stresses. Even impacts due to minute deflections, such as those in ball or roller bearings, produce audible sounds. A cumulative effect is produced by inaccurately spaced or inaccurately formed teeth, by the deflection of the transmission shaft and by some deflection in the bearings and their mountings. Non-resonant materials, like compressed cloth and rawhide, have lower densities and elasticities than steel. Hysteresis has a damping effect on the sound wave. Friction in gears probably becomes more important as the surface becomes rough.

Among the expedients suggested for reducing noise are greater accuracy in manufacturing the gears, better alignment, greater rigidity of mountings and the giving of greater consideration to the relation that tooth numbers have to the size of the gears and to their pitch-line velocities and loads.

For producing better transmissions four methods are suggested: (*a*) experimentally varying the proportions of parts and determining the most effective elements that make for quiet gears; (*b*) gradually increasing knowledge and skill by the usual evolutionary methods and by improving the methods of accurate manufacture, such as the introduction of grinding machinery; (*c*) determining the causes of noise and providing means of producing desired effects by selecting the proper materials and correcting manufacturing methods and (*d*) administering corrective methods, that is, making gears as accurately as possible, then grinding the tooth-forms to the prescribed degree of accuracy.

IN the early development of the automobile, engineers were concerned chiefly with producing mechanisms of mechanical utility, that is, effective and durable power-transmitting mechanisms. Aesthetic considerations were desirable, but of altogether inferior importance.

The invention of the sliding-gear transmission, which replaced a multiplicity of individual clutches, was a great improvement as a mechanical device but did not fulfil its creator's highest aspirations; his figurative characteristic, "It's brutal but it works," gives his accurate appraisal of a brutal noise-maker but, nevertheless, a practical mechanism. Since those early days, the sliding-gear transmission has withstood all onslaughts of inventive genius to replace it, regardless of the efforts of recent years to produce more smoothly and more quietly running cars, efforts that have been given great impetus by an evolution marked by great mechanical advances and increased knowledge. Yet, figuratively, mechanical practicability still holds the spotlight, smoothness and silence standing in the wings waiting hopefully. Now the effort toward smoother and more quietly running cars is even greater, partly because of the reflex of greater popular understanding and expectation, partly because of the generally higher engine-speeds employed and the more general use of closed bodies. In the transmission, this effort to improve running-quality has been directed chiefly toward gears.

Some Pertinent Questions

We all understand in a general way the causes of noise in transmissions, and we know that if these causes are eliminated so will be the noise. The question is then, Can we eliminate the causes and, if not, can we control or handle to advantage the noise after it has been created? To answer this, we must inquire further into the nature of sound and the causes of noise in transmissions. Some pertinent questions naturally suggested by such a study are

What is noise?
What are its characteristics?
Are the noises accentuated or can they be subdued?
Can we do anything to reduce the effects of noise on our senses; that is, are some noises more noticeable or disagreeable than others?
How much have the gears to do with noise?
What about the influence of other parts of the transmission?
How much has gear accuracy to do with noise; if we made perfectly geometrical gears, would they run silently?
How about materials?

It is not proposed here to answer these questions, for they are as yet problems for further investigation; but I shall give a short review of some of the elemental principles involved.

[1] M.S.A.E.—Engineer in charge of design analysis, Packard Motor Car Co., Detroit.

Sound, which includes all noises, is the sensation produced through our organs of hearing. The physical basis of sound and its communication elicited the curiosity of man many generations ago, and today, as a result of the work of many scientific investigators, a fairly clear understanding is extant.

Nature of Sound

Experimental evidence indicates that sound originates in vibrating bodies and is communicated by vibration in material bodies. Three important facts indicating the nature of sound are: (*a*) Sound is not communicated through a vacuum; (*b*) the motion of sounding bodies is such as to cause wave-motion or vibration and (*c*) the velocity of sound agrees with the velocity of the compressional waves in any material medium.

That sound requires a material medium, either from which to originate or through which to be communicated, is shown by the experiment illustrated in Fig. 1 in which a ringing alarm-bell is placed in a sealed bell-jar from which the air is gradually exhausted. As the air is exhausted, the sound becomes fainter, until it can no longer be heard, no matter how vigorously the bell may be ringing inside the jar; as air is allowed to re-enter the jar, the ringing is again heard. In this experiment, the bell must be supported on a mass of soft cotton, for otherwise the sound will be heard because of the vibrations in the supports leading outside the jar.

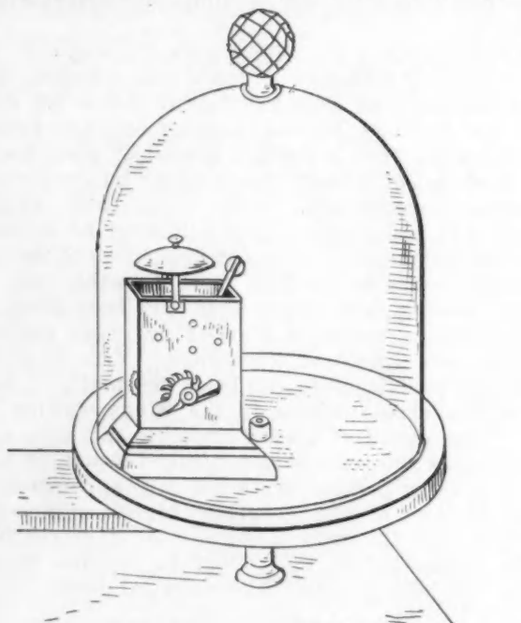

Fig. 1—Experiment Illustrating That Sound Requires a Material Medium Either from Which To Originate or through Which To Be Communicated
If a Ringing Alarm-Bell Is Placed in a Sealed Bell-Jar from Which the Air Is Gradually Exhausted, the Sound Becomes Fainter and Fainter as the Air Is Exhausted

All sources of sound are vibrating bodies capable of setting-up vibrations in the air. Plates, bars or rods, bells, tuning-forks, strings and musical instruments are examples. Vibration in plates has been studied by the configurations caused by the vibration of fine sand particles previously sprinkled on the surface of the plates. The sand, as shown in Fig. 2, gathers at the points on the plates at which there is no movement and is thrown off from other points. Other means of studying vibration show a definite correlation of the vibrations in the sounding body and the sound produced.

The velocity of sound in a given medium is the same as the velocity of all the compression waves in the same medium, whether it be air, water, steel or, in fact, any gas, liquid or solid. Velocities have been studied in all media; in air, by observing the difference in time between the flash and the report of cannons at a fixed distance from the observer. These sound velocities, like compressional waves, depend on the elasticity of the media, being higher in media having greater elasticity. Thus, the velocity of sound in steel is about 15 times as great as it is in air.

Sounds that have a sustained and simple character are called tones or musical sounds; abrupt and sudden sounds are called noises. Noises, however, may also result from a mixture of discordant sustained sounds.

The pitch of a sound depends on the number of vibrations per second, called the frequency of the vibration, higher frequencies producing sounds of higher pitch.

The loudness of the sound is ordinarily called its intensity. This depends on the amplitude of the vibration in the wave, loudness being increased by an increase of amplitude. The two are not proportional, however, high-pitch sounds generally seeming more intense than low-pitch sounds. As the lower end of the range of human hearing is reached, a great amount of wave-energy is necessary to cause sensation and below this range, vibrations great enough to be felt cannot be heard.

Sounds may be intensified or diminished. The megaphone or the sounding-box of musical instruments are good examples of intensifiers.

Vibration in Transmissions

What has this to do with transmissions? We have seen that the source of all sounds and noises is vibration; hence, a study of the eliminating of the source of noise becomes a study of the elimination of certain kinds of vibration. Let us consider, then, the sources or causes of vibration in transmissions.

Vibrations are set up in a body when it is subjected to change of shape, either local or general. Material bodies possess weight and therefore inertia and, being elastic, tend to resume their normal shape; hence, waves of stress are set up, and these waves, as we have seen, become sound-waves when their frequency or wave-lengths come within the range of hearing. These waves may be set up by the direct impact of bodies, by rubbing, or by changing any applied loads or forces. Stress waves can cause impacts between bodies. A simple experiment, illustrating this effect, is shown in Fig. 3, a ball being thrown from the end of a rod by the vibrations set up in the rod when it is rubbed briskly with a piece of cloth.

Evidence showing the amount of noise that may be caused by impacts due to minute deflections is found in high-grade anti-friction bearings, such as ball or roller bearings. For instance, high-grade ball-bearings are made with almost uncanny precision and the departures from true geometrical shape are measured only in tenths of thousandths or hundredths of thousandths of an inch.

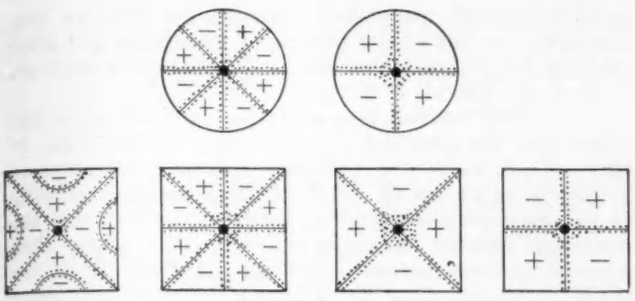

FIG. 2—ALL SOURCES OF SOUND ARE VIBRATING BODIES
If a Plate That Has Been Previously Sprinkled with Fine Particles of Sand Is Caused To Vibrate, the Sand Will Gather at the Points on the Plate Where No Movement Occurs and Be Thrown Off at the Others, Thus Giving the Patterns Shown

Made with such great accuracy, they might be expected to run silently; yet, under the action of load and speed, such bearings may give rise to very audible sounds. Under the action of load, the balls and the races, following the laws of elasticity, must deflect slightly at the points of contact, and the ball under the load assumes a very slight egg-shaped form. At slow speeds the changes of form take place slowly, but at high speeds the changes take place so rapidly that stress waves of high frequency are set up and these waves cause impacts between the elements of the bearing.

How does this apply to a pair of running-gears? In the tooth action of involute spur-gears, a pair of teeth come into engagement, then partly roll and partly slide on each other in varying amounts and then go out of engagement; during the meshing cycle of one pair of teeth, an overlapping cycle of another pair of teeth begins. We know that if the teeth are inaccurately spaced and inaccurately formed, or the engaging surfaces are rough, impacts of considerable magnitude will occur in the engagement of the teeth. These impacts may be augmented by the deflection of the transmission shafts, small deflections in the bearings and mountings and even by the deflection of the gears themselves. The effect is cumulative, like a row of dominoes; if the first one is knocked down, all will fall.

Materials have important acoustical properties. We have seen that density and elasticity are two properties of material bodies that are necessary to support wave motion or sound waves. Resonant materials, like steel, when compared with materials like compressed cloth and rawhide, are found to have much higher densities and elasticities; hence, wave motions started by impacts, as in gear-teeth, set up waves of very low frequency; hence, large impacts can scarcely be heard, except when transmitted to the metal shafts and mountings. Another property, known as internal friction or hysteresis, is important; this property determines the damping effect on the sound wave. Gears made to ordinary standards of accuracy run more quietly than metal gears for these reasons, but such gears must be very much larger than steel gears to transmit the same power; compactness of transmission commits us to the use of very strong and very elastic materials, and these are the most resonant. This shows the need of reducing the impacts between gear-teeth to the lowest possible amount.

Friction in gears might be given some consideration, because the direction of the force of friction changes as the tooth contact approaches the pitch-line and then recedes from it. That is, the direction of the force of friction reverses at the pitch point and also changes in amount during the action of a pair of teeth. This generally is very small; and it is doubtful how important an element it is in obtaining the quiet running of gears having smooth tooth-engaging surfaces, but when these surfaces are rough it probably becomes more important.

PRACTICAL EXPEDIENTS

Thus, the limit of elimination of the causes of transmission noise will be reached when we can produce mathematically perfect gears and mountings; even then, if made of resonant elastic materials such as steel, they probably would not run absolutely silent because of the deflection impacts.

Let us assume that we must have a certain amount of deflection, hence some noise. We have at least a chance to avoid amplifying this noise; and if we find out how it can be done we might even build transmission-cases to absorb the sound-waves before they reach the air or other parts of the car.

We also have, to a certain degree, a choice of the kind of noise we must tolerate; we can choose a high-pitch or a low-pitch noise; we can choose between an unpleasant noise and one that does not attract enough attention to bother us.

A number of possibilities for the improvement of the running quality of transmissions therefore appear. The direct causes of noise, that is, the impacts of the gear-teeth, can be reduced by greater accuracy in manufacturing the gears and better alignment and greater rigidity of the mountings and the shafts. Then there is the possibility of subduing the noise, or at least of avoiding amplifying it, by a study of transmission-case design; and also of taking advantage of the fact that some noises seem softer and less disagreeable than others, by giving consideration to the relation that tooth numbers bear to the size of the gears and their pitch-line velocities and loads.

Apparently three or four methods of commercially producing better transmissions are available, but the standard that is set fixes to a large extent the methods finally to be employed in manufacture, and hence very largely influences the procedure to be used in the study of transmission improvement.

One method is to start out by deliberately exhausting

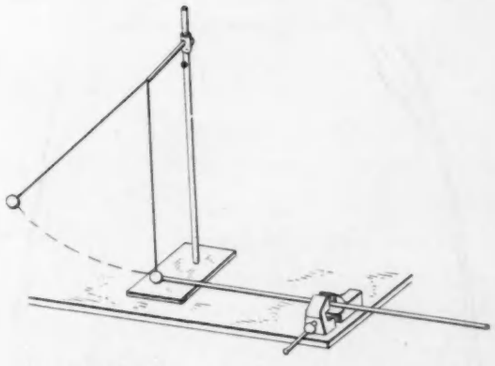

FIG. 3—HOW VIBRATIONS CAN BE TRANSMITTED
If the Middle Point of the Rod Is Clamped in a Vise and One End Rubbed Briskly by Quickly Drawing the Hand with a Firmly Grasped Cloth That Has Been Dusted with Powdered Rosin Off the End, a Small Suspended Ball Touching the Other End of the Rod Will Be Violently Driven Off by the Longitudinal Vibration

the experimental possibilities. By that I mean trying different tooth-forms, or trying different sizes of teeth. One might try different diameters of shafts, various bearing mountings, shapes of the case and other details,

and deliberately, by a method of elimination, determine the most effective elements that make for the production of quiet gears.

The second method, which is probably more general, is evolutionary in action. By that I mean the ordinary evolution that takes place in a manufacturing establishment, namely, making use of the gradual increase in the fund of knowledge and skill acquired in making and designing gears and their mountings, the improvement in gear-making machinery, and the introduction of new methods of more accurate manufacture, such as grinding machinery.

The third method of attack is to determine the causes and to provide means of controlling them to produce the desired effects. This would have to do with determining the factors that make for noise and obtaining the best possible transmission design for controlling these factors absolutely, such, for instance, as selecting the proper materials and providing manufacturing methods to control the tooth spacing and form, concentricity run-out or axial alignment, mountings, machine fits and the like, through each step of the process of machining and heat-treating the transmission parts. This method, perhaps, is the most difficult of all.

The fourth method is a partial control of cause and effect, plus the administration of corrective methods. In this method, we control the early stages of manufacture as closely as we see fit. We cut the gears as accurately as we can conveniently. We heat-treat them so that the minimum amount of distortion will take place, then apply corrective methods, such as the grinding of the tooth-forms and other parts accurately or as accurately as the selected standard prescribes after all the preliminary steps have been taken.

At the present time all these methods are being applied to some extent. Only recently, the improvement in gear-grinding machinery has given the fourth method, that of applying corrective measures, a great stimulus. The best way of making gears that is cheapest will be the method that will be used.

THE NEED OF GRINDING CARBURIZED AND HARDENED GEARS

BY O. H. SCHAFER[2]

GRAPHICAL demonstration is given of the desirability of grinding gears that are made of carburized material. The warping of carburized gears is shown to be due to the shrinking of the carburized metal. The teeth cut on the regular commercial type of hobbing machine vary in form; those cut on a simplified hobbing machine are more accurate. Tooth forms made from oil-treated steel are much better than those made from carburized and hardened steel. The conclusion is that carburized gears must be ground, but when oil-treated and accurately cut on a simplified hobbing machine grinding may be necessary only when the teeth have become mutilated.

[2] Studebaker Corporation of America, Detroit.

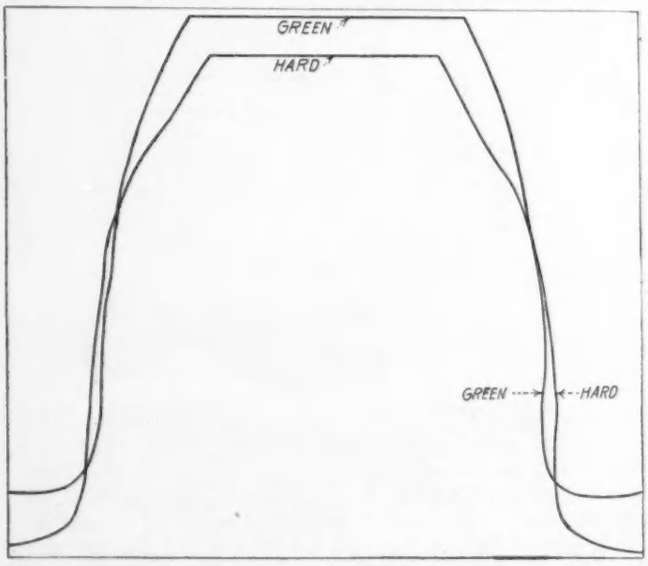

FIG. 4—A GRAPHICAL REPRESENTATION, SOMEWHAT EXAGGERATED, OF HOW CARBURIZED GEARS WARP

The Carburized Metal Seem To Shrink Causing the Top of the Tooth To Become Narrower and the Bottom To Widen Due to Shrinkage of the Portion at the Bottom between the Teeth

THE Studebaker Corporation has found it desirable to grind gears, when they are made of carburized material and have been produced on a more or less inaccurate commercial-type gear-cutting machine. For several years we have run numerous tests on the distortion of gear teeth, the results of which I shall attempt to show.

In Fig. 4 we have a graphical representation, somewhat exaggerated, of how carburized gears warp. The carburized metal seems to shrink, causing the top of the tooth to shorten in width and the bottom of the tooth to widen, due to the shrinking of the portion at the bottom between the teeth. The same tooth is shown in the green state and after hardening. Fig. 5 shows tooth curves of gears produced on the regular commercial type of cutting machine; you will note that they vary in form. This method of charting is familiar to those who have followed gear-cutting. In this particular diagram the full line represents the drive side of a gear tooth, and the dash line the coast side. The variations show that the coast side and the drive side do not coincide; note the variations between the drive sides and the different coast sides. In other illustrations, you will note that they do coincide. The spacing between the teeth is very irregular. Each dot represents a tooth, and each vertical space represents 0.001 in. The variations of 0.007 and 0.003 in., or a total of 0.010 in., indicate the cumulative error in 90 deg.

Fig. 6 shows the tooth curves of the gears as they come from a simplified hobbing-machine. Here the drive sides, that is, the full lines, coincide with one another, and the variations between the coast sides and the drive sides are very slight. The spacing is not shown but is usually a straight line, which indicates no error at all.

In Fig. 7 are shown four teeth of one gear, the coast sides above; the drive sides below, in the green state, after carburizing and after hardening. The full line indicates the curves of teeth in the green state, the dash line of the teeth after carburizing and the dot-and-dash

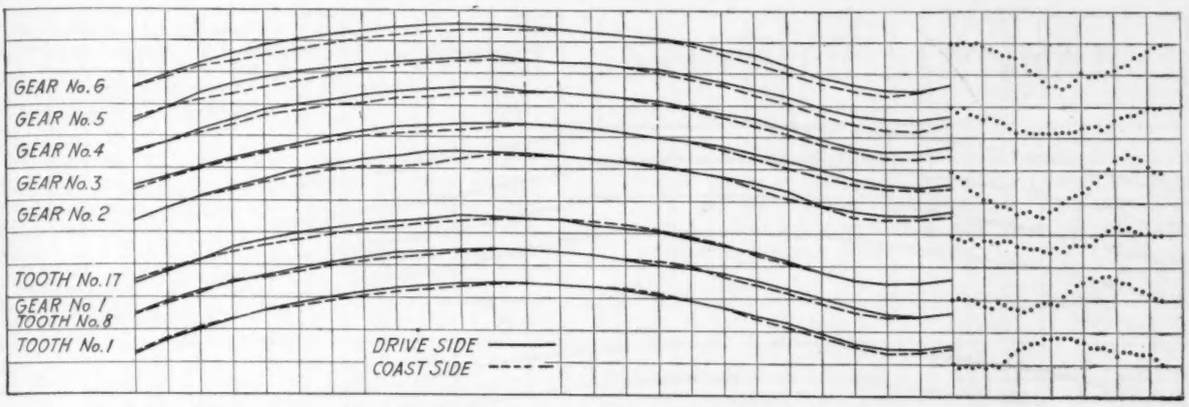

FIG. 5—VARIATION IN THE FORM OF TEETH PRODUCED ON A COMMERCIAL GEAR-CUTTING MACHINE
The Variations between the Drive Side, Represented by the Full Line, and the Coast Side, Represented by the Dash Line, Should Be Noted

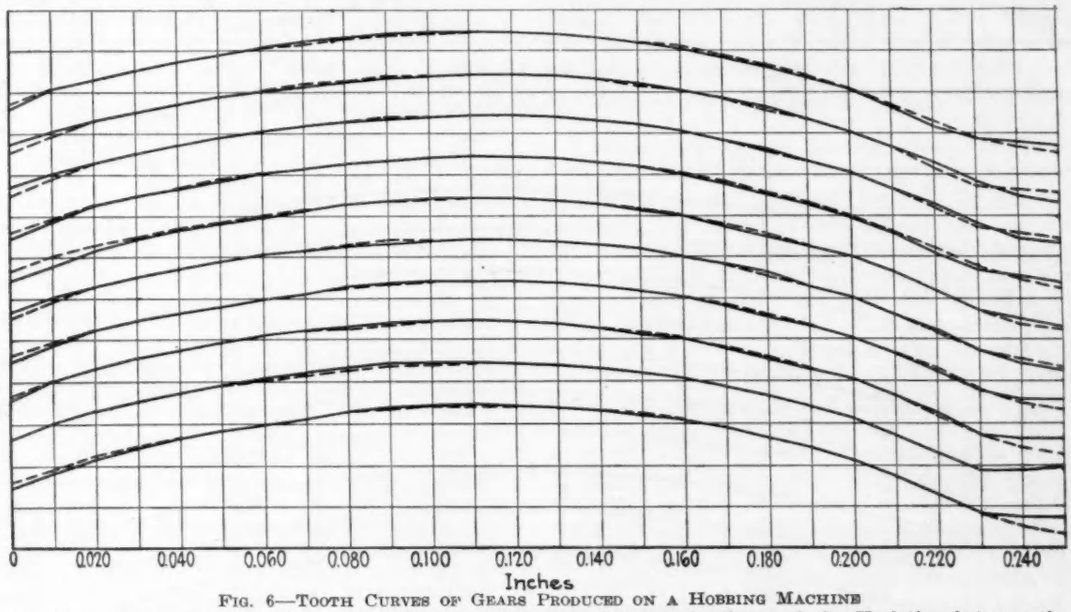

FIG. 6—TOOTH CURVES OF GEARS PRODUCED ON A HOBBING MACHINE
The Drive Sides, Represented by the Full Lines, Coincide with One Another and the Variation between the Coast and the Drive Sides Is Very Slight

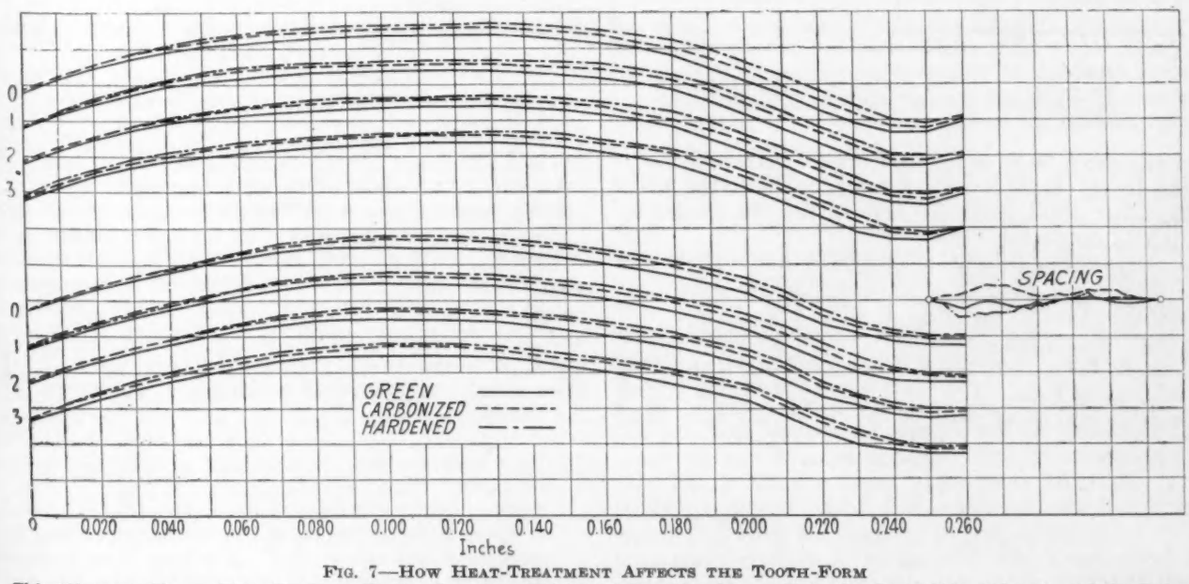

FIG. 7—HOW HEAT-TREATMENT AFFECTS THE TOOTH-FORM
This Diagram Shows How the Four Teeth of a Gear Thickened Considerably on Both the Coast Side (Above) and the Drive Side (Below) after Carburizing and Even More after Hardening

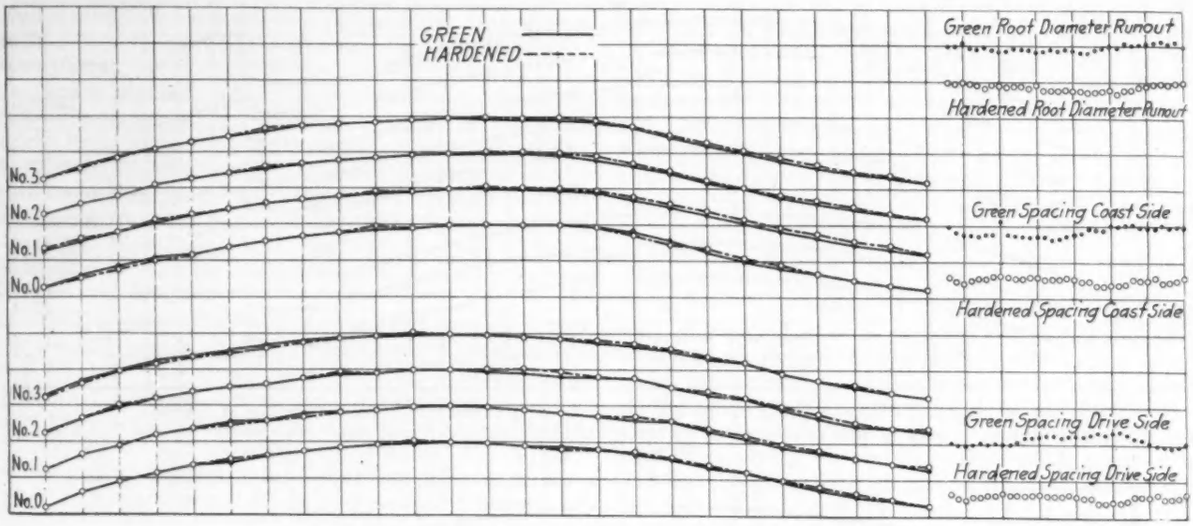

FIG. 8—TOOTH CURVES FROM OIL-TREATED STEEL GEARS
Very Little Change Is Noted as a Result of the Heat-Treatment, the Teeth Tending To Thicken Slightly at the Roots. A Comparison with Fig. 5 Will Show the Superiority of This Method of Heat-Treatment

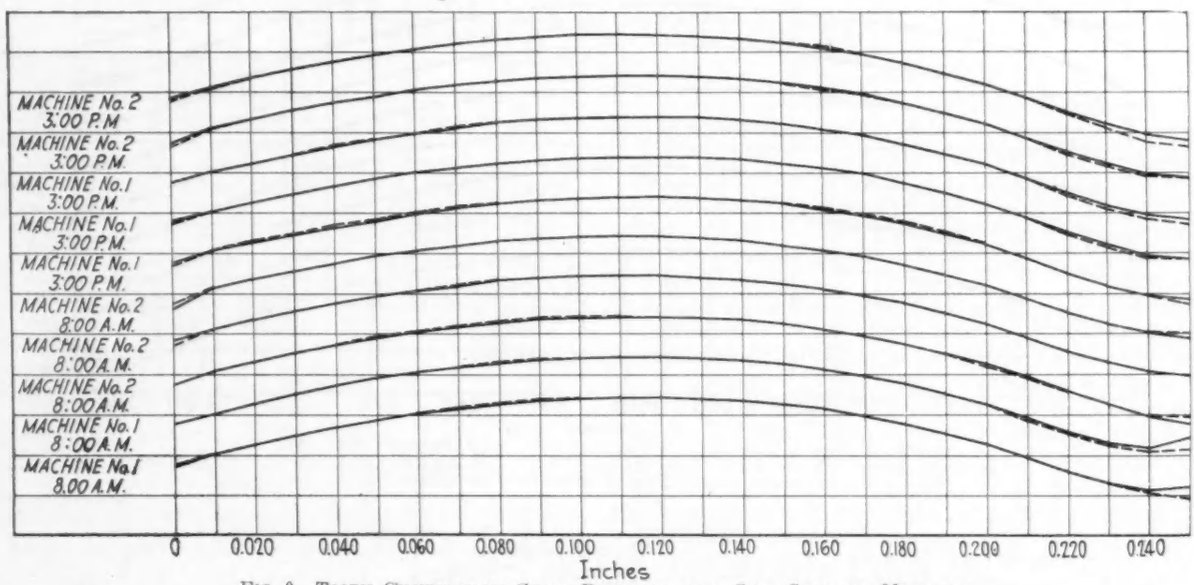
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FIG. 9—TOOTH CURVES FROM GEARS PRODUCED ON A GEAR-GRINDING MACHINE
In This Case the Coast and the Drive Sides Coincide Very Closely with Each Other and the Spacing Is Accurate

line of the same teeth after hardening. After carburizing, the tooth thickens considerably on both the drive and the coast sides, and still more after the hardening operation is completed.

The tooth-forms in Fig. 8 are from oil-treated steel gears. The teeth tend to thicken at the roots but not appreciably. Comparing Fig. 8 with Fig. 7, you will notice that the former shows very much the better gear. Fig. 7 shows the carburized and hardened steel, and Fig. 8 the oil-treated steel. The tooth-forms shown in Fig. 9 are the drive and coast sides of the teeth that have been ground on a gear-tooth grinding machine. The sides coincide very closely; the error is unappreciable. The spacing, as in the simplified hobbing-machine, usually shows a straight line, which means no error in spacing.

The illustrations indicate that it is necessary to grind gears that must be carburized, which include rear-axle spiral-bevel gears. When oil-treated steel gears are used and are accurately cut on the simplified cutting equipment, grinding may be necessary only when the teeth have become mutilated in handling, or for other salvaging purposes.

OIL-TREATED STEEL AND GROUND GEARS

BY L. A. DANSE[3]

THE Cadillac Company has used S.A.E. 3250 Steel for at least 8 years. This is medium nickel-chromium steel. Many other kinds have also been tried. Experience has shown that transmission gears made of carburized steel are not within 30 per cent as accurate as those made of oil-treated steel. This may be because of the fact that more attention has been paid to oil-hardened than to carburized steel gears. Efforts to control the distortion of carburized gears were unsuccessful. The hardening was done in salt pots, lead pots and open furnaces, heated by gas, oil and electricity. The same thing applies to spur gears. Oil-treated steel for rear axles has not been tried. When transmission gears were made from drop-forged blanks made by the conventional pegged-out process from flat stock they became oval. Upset gear forgings are used as fast as the forging suppliers can become equipped for the work. When a slug is cut from the end of a long bar, then up-ended and drop-hammered, the flow of metal is such that the distortion is much less and the tooth strength greater. When the flow of metal in rolling is in a certain direction the gears will contain flow-lines. Some teeth will be strong because the flow is lengthwise of the teeth; others weak because the flow is across them.

Special impact tests were made. One tooth was knocked out by a drop-hammer impact; then one on the opposite side was broken off. Teeth quartering to each other were found to be of vastly different strength. Teeth drop-forged by the pegged-out method vary in strength depending upon the flow-lines. Upset gear teeth are not so strong as the strongest of the teeth made from oil-treated steel forgings but are much stronger than the average. Upset gears have no weak teeth, for the flow is through the teeth, not across them; the teeth are uniformly strong all the way round.

Ring gears warp. They follow the same rule as regards flow-lines. When they are pegged out flat they try to get back to the flat-rolled bar form. If the ring gear is upset so that the flow is through the teeth it will become slightly distorted but will not tend to become oval. The strength will increase from 20 to 40 per cent, depending upon the skill with which the two methods of forging are executed. Upset gears absorb about 1300 ft-lb. of impact before cracking as against 260 ft-lb. for gears in which the flow is crosswise.

Originally the process used in making transmission gears was to rough-cut them on gear-hobbing machines, then finish to size, harden, wire-brush and match. Through automatic control and electrical furnaces the warpage in heat-treating has been decreased and the uniform expansion can be allowed for. But the greatest improvement has been in the grinding of finished gears. The teeth of gears need be shaped only to 0.0050 in. oversize, leaving 0.0025 in. on a side for grinding. Two gears are shaped at a time, doubling the output; one man runs three machines where he used to run two. Three gear-shaping machines and one man produce the same number of gears that six machines and three men did formerly. Single-purpose hobbing machines cut the time still farther. New hobbing machines not only run faster than the old ones but they do away with gear-shaping machines entirely because the grinding machines will finish hobbed teeth as well as they will finish shaped teeth. Backlash, tolerance and eccentricity are also greatly reduced. In assembling, the advantage is with ground gears as compared with cut gears. Tear-downs are fewer than 6 per cent and the standard of quietness is noticeably better. Scrap has been reduced from 3 to ⅛ of 1 per cent. When the first gear-grinding machines were installed noises in the bearings and other parts appeared that had not been noticeable before. Ground gears save trouble, labor and time and have almost eliminated tear-downs and rematching.

REGARDING the metallurgical aspects of gear-work, we have tried a number of different steels. We have used steels of carbon-content varying from 5 to 65 or 70 per cent. We have used experimentally plain-carbon steel, open-hearth steel, electric-furnace steel; we have used alloy-steels including low-nickel, medium-nickel, high-nickel, low nickel-chromium, medium nickel-chromium, chromium-vanadium, chromium-molybdenum and straight chromium. The Cadillac Motor Car Co. for at least 8 years, and I believe longer, has used S.A.E. 3250 steel for transmisson gears, which is medium nickel-chromium; also nickel steel and carbon steel.

I have great respect for the work that the Studebaker Corporation has done. I am perfectly frank to say that they have us beaten a mile; we have no records or charts such as they have. I am not saying this to start an argument or to arouse controversy; I am simply stating it because it is interesting, in that our experience is different from theirs. We have not found it possible to do a carburized job on Cadillac transmission gears within 30 per cent or more of the accuracy with which we can do an oil-treated job. That may possibly be because we pay more attention to the oil-treated job and less to the carburized, but we thought we were doing a good carburizing and hardening job. We hardened in salt pots, lead pots, open furnaces, heated by gas, oil, electricity. We endeavored to work out a method for the Leeds-Northrup furnace whereby we might control the distortion of carburized gears. We were unsuccessful. Our case-hardened gears have been at least 30 per eent poorer than our oil-treated gears. And that follows all the way down through all the spur gears that we make. I cannot say that for rear-axle gears. We have not had enough courage; maybe we did not have the conviction in the first place, but we certainly did not have the courage to endeavor to oil-treat rear-axle gears. Some day I think perhaps we shall. I should not be astonished if we were to produce an oil-treated rear-axle gear and make a fine job of it.

An interesting thing in connection with our transmission gears is that when we used drop-forged blanks made by the conventional pegged-out process from flat stock, forging a round gear out of a flat, the gear all went oval. You could follow them all over 0.001, 0.002, 0.003, 0.010, 0.100 in. or more. They all went; tried to get back to nature. That is the way we all do some time. Nickel-chromium steel is not different from man; "from dust to dust." That steel tried to go back in the direction from which it was rolled. We are using, if we can get them, we cannot always, but as fast as our forge suppliers can become equipped for the work and give them to us we are using upset gear forgings. In this method a slug is cut-off the end of a round bar, then up-ended and drop-hammered; a drop-forging die is used, practically similar to the die with which we used to make pegged-out gears. By this upsetting method, the flow of the metal is such that we get considerably less distortion, and we get much more tooth-strength; we get uni-

[3] Metallurgist, Cadillac Motor Car Co., Detroit.

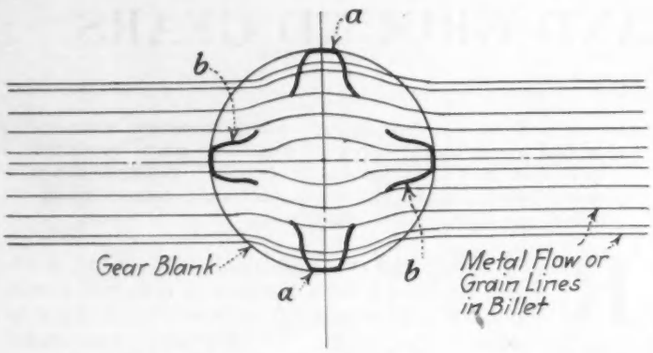

FIG. 10—DIAGRAM SHOWING THE RELATION BETWEEN THE STRONG AND THE COMPARATIVELY WEAK GEAR TEETH AND THE FLOW-LINES IN THE BILLET

If the Path of the Metal Flow or Grain Lines of the Billet Is Across the Teeth as at *a* These Teeth Have Been Shown by Repeated Tests To Be the Weakest Teeth on the Gear. The Teeth at *b* Where the Flow Lines Pass through Them Longitudinally Are the Strongest Teeth

form tooth-strength, and we save ourselves considerable miscellaneous grief.

In explaining better tooth-strength, I can tell you what you probably all know, that when you make a gear out of this kind of blank, in which the flow of the metal in rolling has been in a certain direction, the gear will contain flow-lines. Some teeth will be strong, because the flow is through the teeth, as shown in *b* in Fig. 10; other teeth, as at *a*, will be weak, because the flow is across the teeth.

We built an impact testing-machine at considerable expense. We do not believe in impact testing-machines such as engineers ordinarily use. We made a number of tests and sold the machine practically as junk. We put in a set of stops that mesh with the gear teeth except in a short portion, and then knock one tooth out of the gear by a drop-hammer impact. We measure the amount of impact energy that the tooth absorbs before it breaks. Then we turn the gear around and break out another tooth. That was what put us on the track of this method of upset gears. We found several years ago, in testing gears, that the teeth which lie quartering to each other were of vastly different strengths. We could not reason it out at first. It seemed to follow a set rule. We might break a tooth out and get a reading, then another and get a similar reading and then a third and get a similar reading. But, just as surely as we happened to break one and swing around, we got a different reading. Then we began to deep-etch the gears. We put a blank in a hydrochloric acid solution and etched it until we could see the forging flowlines through the metal. We would do the same thing through all the cut gears. We saw that tooth strength obeyed the law of forging flow-lines. Where the flowlines went through the tooth, as in Figs. 11 and 12, the tooth was strong; where they went across the tooth, as in Fig. 13, the tooth was weak. We tried to get the teeth all the same; and with the upset forged blank they are all practically the same. Very little difference in tooth strength is noticed.

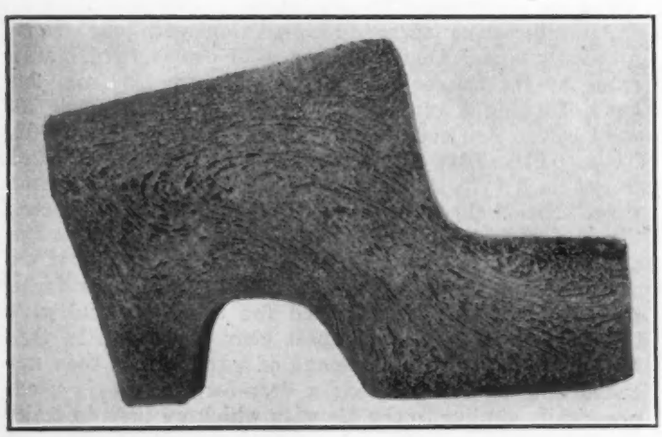

FIG. 11—PORTION OF AN ETCHED RING-GEAR

Note the Uniformity with Which the Flow Lines Run Up into and Down Out of the Tooth

In some gears, drop-forged by the pegged-out method, the teeth are very strong. Other teeth in the old-style pegged-out gears are weak. Still other teeth, between the weak and the strong, are of average strength. This is because the flowlines run into one side of the forging, then split and run around the rim, and come together again at the side opposite to that where they split. Here they run out of the side opposite to that where they ran in. Our upset gears are not so strong as the strongest of the teeth on the old-style forging, but they all are much stronger than the average teeth in the old style. The upset gears have no weak teeth. In the upset gear forgings the flow is through the teeth and not across them, so we get uniformly strong teeth all the way around the gear.

That set us thinking about ring gears. Ring gears warp. They follow the same rule. If you peg them out of the flat, they will try to go back to the flat-rolled bar form. You may succeed in holding them in dies, if the machine and the dies are good enough, but they try to get back. Internal stresses are set up when they are quenched. If you upset the ring gear so that, instead of the flow running round the gear, it runs through the teeth, you will find that the gear will try to return to the original bar form, but it will distort slightly in the other direction, uniformly around the ring. It will not tend so much to go oval, as the original bar was not of that form. Furthermore, the tooth strength will increase between 20 and 40 per cent, depending on the skill with which the two methods of forging are executed. As I recollect some rough figures of our impact testing-machine, our old drop-forged ring gears, in the weakest portion where the flow ran across the teeth, would absorb about 260 ft-lb. of impact before cracking. The upset gears, at the weakest portion, would absorb about 1300 ft-lb. of impact before cracking; with exactly the same analysis, with steel from the same mill and with the heat-treatments practically identical, with the metallic inclusions similar, so far as we could see under the microscope. Our forging sources have instructions to arrange their equipment so as to furnish upset gear forgings at the earliest date.

TRANSMISSION GEARS BY CADILLAC'S OLD METHODS

Our transmission gears used to be rough-cut on hobbing-machines, leaving about 0.010 in. on a side to finish. They were then finished to size on the shaping machines, ready to harden. After hardening, the gears were wire brushed, and "then the fun began" on matching.

The gear-hobbing machines take from one to seven blanks at a time, depending on the width of the face. On the shaping machines we could do only one at a time, and to get our S.A.E. 3250 steel smooth we had to take two cuts around to take off 0.010-in. finish. That steel is tough and difficult to machine smooth.

If we are to get any kind of results on machining, the forged blanks must be heat-treated right and the

hardness kept within the Brinell limits of from 170 to 217. In the heat-treating inspection 10 gears out of every 100 are tested. If 1 of the 10 is off, the whole 100 is tested, and those that come outside the Brinell limits are reheat-treated.

The heat-treating also used to give trouble. It warped the gears 0.020 in. in open furnaces and lead pots. Of course, since we put in automatic controls and electric furnaces for heat-treating we have an easier time in keeping the gears true in finish-hardening. Now the gears are coming without warpage and with uniform expansion of about 0.005 in. across a 5-in. diameter gear. This expansion can be allowed for.

For finish-hardening, heat-treating gets the gears after they have been shaped to size. Close control with the new hardening equipment has helped greatly and we appreciate all that has been done. Every move that makes it easier to get the finished gears true to size and tooth-form is certainly welcomed.

Economies and Improved Quality Made Possible by Grinding

But the thing that puts us in the way of the greatest improvement yet made was grinding the finished gears. We are all "getting schedule" clear through the shop since the gear-grinding machines started.

Now we hob the same as ever, leaving 0.020 in., but only shape down to 0.0050-in. oversize on the teeth, to leave 0.0025 in. on a side for grinding. That lets us shape two gears at a time and doubles the output. Besides, one man now runs three machines, where he used to run two. Three shaping machines and one man do the same number of gears that six machines and three men used to do.

We are trying also some new single-purpose hobbing-machines that will cut the time again. These new machines will cut eight of the flat 31-tooth gears down to grinding size in 20 min., with one operator to two machines. We have been hobbing seven of these gears in 25 min., one man to two machines, then shaping six in 25 min., one man to three machines. The new hobbing-machines will do away with the shaping machines entirely, because the gear-grinding machines will finish the hobbed teeth just as well as they will the shaped teeth. The new machines will also cut faster than the old ones. This means that one new machine will replace one old hobbing and three shaping machines and the labor will be cut one-third.

That is still in the future, so we shall disregard the new machines and take the job "as is." We used to run 0.010 to 0.014-in. backlash on cut gears to allow for inaccuracy and warpage. Now we run 0.004 to 0.006-in. backlash on constant-mesh gears, and 0.006 to 0.008 in. on others. The tolerance in tooth-spacing was formerly 0.0015 in. It is now 0.0002 in. on ground gears. On eccentricity it was 0.003 in.; now it is 0.001 in. after grinding. The tooth-thickness tolerance is the same as it was, 0.001 in. But the cumulative tooth-spacing error around the 31-tooth gear is now 0.0005 in., where we used to dread to look at it for fear it might be 0.0050 in.

Re-Operations and Scrap Cut Down

In the assembling the ground gears have the advantage over cut gears. In cut teeth, the assemblers had an average of 30 per cent tear-downs in matching gears so that they would be quiet. Sometimes a whole day's production would be held up waiting for a rematch. Nowadays, with ground gears, the tear-downs are fewer than 5 per cent and the standard of quietness is noticeably better.

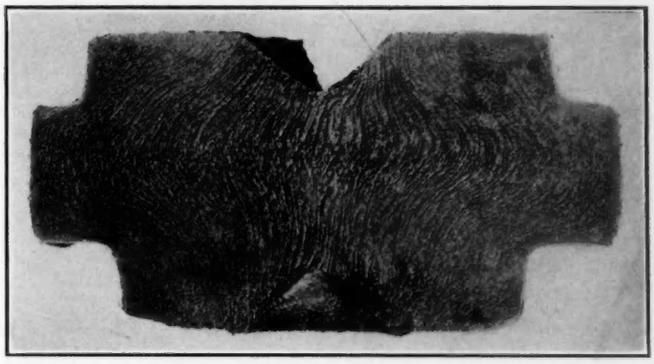

Fig. 12—A Reverse Idler Gear
Another Example of the Flow Lines in the Gear Blank Produced by the Upsetting Process

With cut teeth a certain percentage of actual scrap resulted, due to the warpage and the inaccuracy being so great that the use of gears was precluded. This scrap averaged about 3 per cent. On ground gears, the scrap has disappeared, being about ⅛ of 1 per cent.

Of the 5 per cent of tear-downs now made, it is possible that some are not caused by gear noise, but may be due to bearings or other causes. Since using ground gears we have found that bearings must be improved, as the gears are good enough so that bearing noise has become noticeable.

When the first experimental grinding-machine was started, we made a few sets of ground gears to test the work and feel our way. After we had measured the test gears they were sent into production. Those gears were so good that the next day the inspectors tied up the assembly because everything was noisy in comparison. The ground gears had spoiled the inspectors.

Then the machine was put to work night and day grinding one side of the teeth of constant-mesh gears for use in closed cars. Orders were placed for more grinding machines and we "stormed the castle" until we got machines that would grind both sides of constant-mesh gear-teeth in all transmissions. Additional equipment was ordered rushed in to take care of all the gears that it was possible to grind. We have had the machines a year and like them better and better the longer they are in service.

This is no wonder, for they not only save trouble and labor and time, but the ground gears are nearly perfect. To run quietly, teeth must be true involutes and, if production is to be interchangeable and standardized,

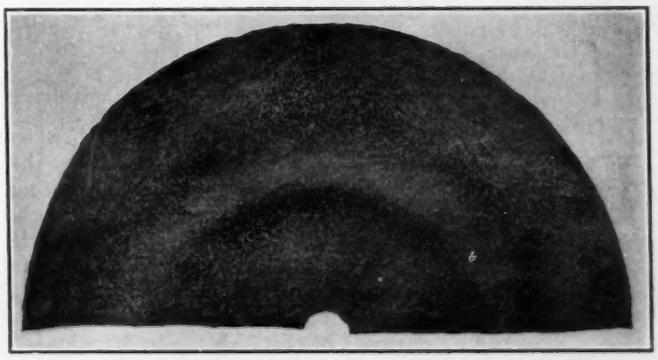

Fig. 13—A Gear Produced by Drop Forging
In This Case the Flow Lines Run into and around the Gear

TABLE 1—GEARS GROUND BY CADILLAC

Type of Gear	No. of Teeth	Pitch Diameter, In.	Face, In.
Countershaft Drive	31	5.166	3/4
Countershaft	25	4.166	15/16
Reverse Idler	16	2.666	1
Low and Reverse Sliding	29	4.833	15/16
Second and High Sliding	22	3.666	15/16
Clutch	16	2.666	3/4

dimensions must be held to closely. Grinding the gears has done these things for us and has almost eliminated tear-downs and rematching.

Making and Measuring Based on Correct Principles

To make teeth in the form of true involutes, one must have facilities to test the tooth curves with a fixture that operates on elemental principles, will itself trace a true involute and will indicate errors of less than 0.0001 in. We have a fixture for each gear; when the ground gears are put on the fixtures they show an error of not over 0.0002 in. On the angular-velocity fixture that plots a chart showing the errors in tooth action, acceleration and deceleration showing as waves in the record line on the chart, and eccentricity also showing, the ground gears draw a true circle, the accuracy to which the gears are ground being beyond the ability of the fixture to measure.

Service records show that ground gears have a much longer life. The smooth surfaces not only show up under the microscope but run more quietly and keep doing it longer. As in the testing fixture, to get a true involute the mechanism of the grinding machine should work along elemental principles. It should, by straight lines and circles, describe true involutes and should so generate the teeth. It will be correct if it generates, and foolproof if it is sturdy and the adjustments are few and simple.

The operations of the machine must be easy, so that it may be entrusted to unskilled labor. Mechanisms must be designed so that adjustments will be maintained over a long period. The gears produced on the gear-grinding machine are listed in Table 1. They are all 6-pitch. They have a short addendum instead of being normal. They are turned off to clear each other when in reverse. The pressure-angle is 20 deg.; the dedendum and clearance 0.193 in.

THE POLISHING AND BURNISHING OF GEAR TEETH

BY R. E. LINN[4]

VIBRATION caused by the roughness of gears cut with a gear-shaping machine cutter, or ground, produces a buzzing sound in the transmission. This noise can be removed by burnishing the teeth. If the gears used in burnishing had the same number of teeth, the neutral spot at the pitch line would not be burnished; but if one gear has one more tooth than the other, the gear will be burnished at the pitch line. After gears have been hardened the noise can be reduced still farther by stoning the teeth and by polishing them with a rubber wheel carrying a polishing compound consisting of tallow and emery or Tripoli. Polishing requires only a fraction of a minute. Holding the polishing wheel on longer makes the gear look as if it were nickel-plated. Polishing takes out the fine lines left by the grinding wheel. The tooth faces of regular gears have a high finish when they are produced by a Fellows cutter having the top angle ground at about 15 deg. instead of 5 deg. Increasing this angle also changes the pressure angle, but so long as all the gears are cut alike the change of the pressure angle will cause no trouble. When gears are burnished the gear is rolled only about 5 sec. in each direction. If it is run too long the tooth contour will break down. A quiet transmission has been obtained without grinding. Grinding takes the warpage out of the gear, but warpage does not produce so much noise as does roughness of the tooth surface. If the tooth surfaces are smooth the gear will be reasonably quiet.

REGARDING transmission noises caused by the roughness of gear teeth and a method of taking some of that roughness out: Considerable roughness will be found irrespective of whether the gear is produced with a gear-shaping machine cutter or is ground. The roughness sets up a certain amount of vibration and causes a buzzing noise in the transmission. One way of taking out part of this noise is by burnishing the teeth. That is, the teeth are burnished by rolling the gear in a set of three gears, two of the burnishers being of different tooth-form from the gear being rolled in the green state.

All these burnishers will be of the same outside diameter and, if you cut 31 teeth in one gear and 32 teeth in another with the same cutter, one will have a greater pressure-angle than the other. The one with the fewer teeth will have the greater pressure-angle. The teeth are cut and can be ground afterward and polished. In burnishing the gear teeth, if the burnishers are all alike, that is, have the same pitch and pressure angle at the pitch line of the gear being burnished, there will be a spot that will not burnish; that spot will be neutral. The burnishing first will be above the pitch line, then below it, except where sliding contact occurs; at the pitch line the contact is rolling. By having a greater pressure-angle on one of the burnishers it will move so that it will burnish the gear at the pitch line. The third gear-burnisher is made about 0.002 in. short on the circular pitch and has a tendency to modify the approaching or top edge of the gear so that it will make an easy rolling contact. This burnishing is done on gears in the green state.

After the gear has been hardened, the little imperfections from the cutter are not so noticeable. Another thing that we found was that after the gears had been hardened we could reduce the noise still farther by stoning the teeth, a long, slow process, and reduce it still more by polishing. For this we use a grinding wheel, commonly called a rubber wheel, shown in Fig. 14. This wheel is not used for grinding; it is merely a medium for carrying the polishing compound. We could not use a rag or a felt wheel. We also tried an iron lap, but that did not work.

The rubber wheel fits into a rack and takes the place of one side of a tooth that has been cut out. The wheel

[4] Assistant general superintendent, Lincoln Motor Co., Detroit.

forms one side of the gear tooth as it does on a gear-grinding machine. This rack is mounted on a steel plate. The gear to be polished is laid on its side on the plate, is held so that it will mesh with the rack, and is rotated by hand through the wheel. The polishing wheel is supported at the back by a steel plate, but not rigidly; the outer edge is left flexible. Under pressure it will flex back out of the way as the gear is rolled through; the wheel is set so that it will move back and not actually grind. We load the surface of the wheel with tallow and emery cake or Tripoli; we generally use emery cake, the same as that used for polishing purposes on plating and similar work.

The man passes the gear tooth through very quickly, holding the tooth in contact with the polishing-wheel only a fraction of a minute; if he were to hold it there longer, it would look as if it were nickel-plated. We have found that it is not really necessary to put on so high a polish. In going through, the wheel does not take out the fine lines, but has a tendency to blend them into a uniformly smooth surface.

If you were to look at the tooth face through a magnifying glass after it has been cut with a Fellows cutter, which we use for finishing, or has been finished with a grinding wheel, you would find the face of the tooth rough. A grinding wheel, in passing through the gear, will leave a little fine roughness on the gear-tooth faces. We have found that a buzzing sound is created by this roughness. Polishing quickly eliminates it.

Anyone who has made Fellows cutters and has tried to cut a gear with one that has just been made will find that it cuts a very rough surface on the tooth; it is essential that the cutter be given a highly-polished finish in order that it will cut smoothly. I have been able to use this idea in polishing gear teeth to a point at which the noise is greatly reduced. It is similar to grinding except that the teeth are not actually ground.

On our regular gears that we cut with Fellows cutters and have hardened and handled very carefully, we get a high finish on the tooth face. We obtain this finish by using a Fellows cutter having a top angle ground at about 15 deg. instead of the standard 5 deg. The cutter then has a tendency to shear the stock and gives a much smoother surface to the cut gear. This also changes the pressure angle slightly at the same time. But, so long as all the gears in a set are cut the same, this change of the pressure angle causes no trouble; we have found that it is immaterial. A gear will work just as efficiently if it has a 19-deg. pressure-angle as it will if it has a 20-deg. pressure-angle. We find that this method of grinding a 20-deg. cutter approaches very closely a 19-deg. pressure-angle and gives a fine finish on the tooth face, but it is not fine enough to avoid all noise.

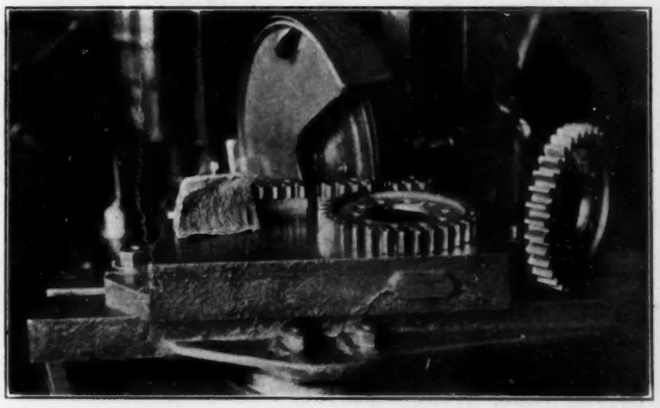

FIG. 14—RUBBER WHEEL USED FOR BURNISHING GEAR TEETH
Burnishing the Gear Teeth Removes the Imperfections Left by the Cutter and Reduces the Noise. The Wheel Used in This Process Does Not Grind the Teeth but Merely Serves as a Medium for Carrying the Polishing Compound

Again, regarding the burnishing of the gears, the gear is rolled only about 5 sec. in each direction. The pressure is not excessive. If it is run too long the tooth contour will break down; you cannot force gears together in the green state very hard or run them very long without destroying the tooth contour.

We have tried ground gears and are still trying them, but up to the present time we do not grind our gears; we have been able to get a very good and quiet transmission without grinding. If we can get a better transmission by grinding we shall certainly do so. One thing that can be said in favor of the grinding machine is that it takes the warpage out of the gear. We have found that warpage does not produce so much noise in the gear as does the actual roughness of the tooth surfaces. If the tooth surfaces are smooth, the gear will run reasonably quietly.

CHECKING TOOTH-FORMS BY THE COMPARATOR

BY W. G. HILDORF[3]

IN investigating the causes of transmission-gear noises the contours of teeth were found to vary greatly from the involute curve. Most of the trouble was found to be with cutters that had been ground or sharpened several times. To observe these variations a device called a comparator that throws a magnified image of gear teeth on a screen was developed. Every cutter before being used is not only checked with the master chart and indexed from tooth to tooth, but is used to cut two gears that are rolled together on the comparator. Rolling gives a means of checking and also greater accuracy than simple indexing. The cutter is checked again after it has been sharpened a few times. Variations after sharpening are checked by a machine similar to the one for checking involute curves, the limits being set by the comparator. Cutters that do not meet the tests are scrapped or used as roughing cutters. Burnishing has been tried but does not seem to improve the finished gears materially. In a number of forgings that were treated, variations of warpage and hardness were found in gears made from steel of different heats. Straight-carbon and chrome-nickel steels also show warpage. Steels that warp more than others, when treated under the same conditions, are abnormal, that is, they do not carburize properly, the excess cementite not existing as a fine unbroken network. Normal steel should be specified for many parts. It is difficult to obtain now but in the future probably will not be so difficult.

The electric furnace for the treatment of normal steel is of great help, for the warpage is slight and the gear will be very close to size. Larger parts are carried through without the use of trays or plates.

[3] Engineering department, Reo Motor Car Co., Lansing, Mich.

By drilling 1-in. holes with 3/8 in. of metal between them in the plates for carrying small parts, the cost per pound of metal has been cut down to 0.26 cents.

A FEW things we are doing at the Reo factory that the previous speakers have not mentioned may be of interest. I shall begin with our way of checking the Fellows gear-shaping machine cutters. Several years ago while investigating the causes of transmission-gear noises we found enormous variations in gear teeth; that is, the contours of the teeth varied from an involute curve. If the curve had been fairly uniform from gear to gear, our case possibly would not have been so serious as it was, but a decided variation from cutter to cutter was noticed. In fairness to the Fellows Gear Shaper Co., I wish to state that this was not entirely due to the cutters' being wrong when they were new. Most of the trouble was with cutters that had been ground or sharpened several times. Finally we developed the gear comparator. I believe you are all familiar with the way in which it is used to throw magnified shadows of gear teeth on a screen. We made master charts of a satisfactory cutter and the gear that it produced. Every cutter before being used is not only checked with the master chart and indexed from tooth to tooth, but is used to cut two gears that are rolled together on the comparator. The rolling gives us a means of checking and an accuracy that is much greater than can be obtained by simply indexing the cutter on the chart. When a cutter has passed this inspection it is put into use, but will be checked again after it has been sharpened a few times. We find that cutters do not always cut a gear with the same tooth-form after they have been ground down, say, 1/32 in. Our first clue whether the tooth-form has been changed is obtained from a machine very similar to the one for checking involute curves that has already been explained. The comparator is used to set the limits for this machine. If the machine shows that we are getting near the limit of accuracy, as called for on the gear comparator, a set of gears is cut with this cutter and rolled on the gear comparator. If this test shows that the cutter does not meet the requirements, it is scrapped or used as a roughing cutter. Each cutter is marked, and a record is kept by a card-index system. We have a man whose duty it is to check daily gears from every cutter in use. As an aid to this inspection each machine has a tag which bears the number of the cutter that is in use. Since using this method of inspection we have had comparatively little trouble in maintaining a uniform product. We have also done considerable work along the line of using three gears for burnishing, as has been mentioned by Mr. Linn. We found that a beautiful job of burnishing could be done, yet it did not seem to improve the quality of the finished gears materially.

We have learned a new thing that may be out of place to explain in a gear meeting, but since Mr. Danse has talked metallurgy, and since I am also connected with that branch, you will probably give me permission to mention it. We also upset a large number of our forgings in the way Mr. Danse has explained. This is mainly to give uniform strength around the circumference and to reduce warpage, particularly the warpage that makes the part oval in shape. As an example, our ring gears are made in this way, yet we have found decided variations in warpage and variations in hardness in gears from different heats of steel. The gear was made from 3½-per cent nickel electric-furnace steel. We have also noted a variation in warpage in straight-carbon and chrome-nickel steels. In every case that we have investigated, and we have made hundreds of tests, we have found that when a steel warped more than another steel treated under the same conditions the steel was abnormal. By abnormal steel, I mean a steel that will not carburize properly; that is, its excess cementite does not exist as a fine unbroken network. Our tests are by no means complete, but we have been watching this condition for over 2 years and are specifying normal steel for many parts. Since the adoption of normal steel we have had no soft spots and the steel does not warp excessively, what warpage is present being very uniform from gear to gear. It has been very difficult to buy this steel, because few mills could make it. A large number of them, however, have been experimenting with it and it should not be so difficult to obtain in the future.

The electric furnace is a great help in the heat-treatment of gears for the reason that if one has normal steel and heats it at the proper rate and quenches it from the correct temperature very little warpage will occur, and the gear will be very close to size. The furnace we use was made by the Gleason Works. It is about 20 ft. long. The heating elements are placed along the sides of the furnace. The temperature is controlled automatically. The work is carried through the furnace on revolving rollers, spaced 6 in. from center to center. An adjustable-speed motor drives the rolls through gearing. All the larger parts, such as ring gears, are carried through the furnace without the use of trays or plates. When the furnace was installed we expected to heat the gears for 0.3 cent per lb. of metal at a cost of 2.5 cents per kw-hr. We found that we were not actually doing this, so we drilled 1-in. holes in the 3/16-in. trays that were used to carry the small parts through the furnace.

By drilling these 1-in. holes so that there was only 3/8 in. of metal between them, the weight of the plates going through the furnace was cut down enormously. This brought the cost per pound of metal to 0.26 cent. It was also found that the drilled plates did not warp so much as the solid ones. All gears are heated in this furnace. After the transmission gears have been hardened and ground they are inspected and paired. All gears that do not pass this inspection will have their teeth ground. If a careful check is maintained on cutters and machines it is possible to produce a very uniform product without grinding many gears.

IMPORTANCE OF ACCURACY OF TOOTH-FORM

BY A. H. FRAUENTHAL*

GEARS are ground to make them more quiet; the trick is to find out how quiet they should be made and what expense should be incurred to make them quiet to that extent. The gears in Chandler cars are not ground. Medium-priced cars cannot go to great expense to make gears quieter than those of their competitors. Formerly, carburized nickel-steel gears were used; now chromium oil-treated steel is used, because the distortion is less. Every detail of the process of machining and gear-cutting should be done as well as possible. It is not difficult to heat-treat gears if they have been properly annealed previously to ma-

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chining. Gears on Cleveland cars are burnished in the green state in a manner similar to that described by Mr. Linn. But only 5 sec. is consumed on the reverse and 5 sec. on the forward side. The workman is on a piecework basis and no demand as to time is made so long as the quality is right. The modification that we found desirable is cut into the tooth, which is burnished as nearly as possible to the involute form.

A fairly smooth gear is obtained by watching the scaling during the hardening. Unusual quietness is secured by burnishing gears after hardening. No special method is used to make cluster gears quiet except to make them as carefully as possible. In high-speed Fellows gear-shaping machine cutters that are equipped with steady rests for work arbors all the backlash is put into the large driving gear on one end; the small reverse gear is on the other end. In burnishing cluster gears having three medium-size gears and a reverse gear at the end it was found that although almost the entire weight of the cluster gear overhung the reverse gear no eccentric motion was observed. In the traffic transmission 10 gears are in constant mesh, full teeth are used instead of stub and, consequently, interference at the tops of the teeth is avoided. The only way to make gears quiet is to begin at the bottom, taking exhaustive care from the annealing of the forging, through the blanking, gear-cutting and burnishing. Burnishing may spoil a gear as well as improve it. Considerable study is required to determine just how it should be burnished.

MR. HERRMANN was kind enough to tell me when he was in our plant a few weeks ago that we had quiet gears. We do not grind gears. I am not against gear grinding, but I think there ought to be some way of deciding whether gears should be ground. Gears, as I understand it, are ground mainly to make them quieter. We can all make gears quieter. The trick is to find out how quiet we should make them and to what expense we can go in making them quiet to that extent. As a general rule, medium-priced cars, in which class is the Chandler, must have gears as quiet as those of their competitors; and I believe that not many cars in that class can go to a large or unusual expense to make their gears a little quieter.

We formerly used carburized gears of 3½-per cent nickel-steel, 0.150 to 0.25 per cent carbon. We are now using chromium oil-hardened steel. It is 0.47 to 0.53 per cent carbon, 0.80 to 1.10 per cent chromium. We do not get nearly the distortion with oil-treated gears that we got with carburized gears. I think that has helped considerably in getting a much quieter transmission. When we began using oil-treated gears the manufacturing division was considerably concerned, for it feared the increased sensitiveness of this steel over what we had used before. Consequently, we checked-up our heat-treating process and improved it in every possible way but were not satisfied with this procedure alone. So, we began at the beginning of the machining and made truer blanks than we had been formerly. We did the gear cutting a little better than we had been doing it before. In fact, we are doing it as well as we know how; we guard against every possibility of error of which we have knowledge. When we got into the hardening, we found it was not so great a trick to heat-treat the gears after all, so long as the stock was properly annealed previously to machining. We use Leeds & Northrup hump furnaces and guard very carefully against any uneven heating that might cause distortion or leaks that might cause scale.

Previous to hardening we burnish in the green state in a manner similar to the method Mr. Linn portrayed, but with one difference, however. They work about 5 sec. on the reverse and 5 sec. forward. We consume about 5 sec. and find that this takes care of both sides of the teeth. Our burnishing gears are mounted on a Whitney hand milling-machine, and after setting the table to the correct height, according to the pitch diameter of the gear to be burnished, we push the table back against the regular stop provided on the machine. The workman is on a piecework basis. All we do is check the quality of the product. So long as he gets them right, we do not demand that he hold them there for 5 sec. That gives us a very smooth tooth in the green state. When we began, we cut something that was like a true involute curve. We thought then that we should modify the tooth on the burnishing machine, which we did; but it did not work out successfully. It seems that we worked the metal a little too hard and when we hardened it we got some distortion. Therefore, we cut the modification into the tooth and burnish as near as we can to this form, which is very much more successful.

Next, we found that we got a fairly smooth tooth so long as we watched the scaling in the hardening. Then we went one step farther and burnished some gears after they had been hardened. We use the same machine and get slightly smoother teeth with considerably more initial quietness, which is a very good thing if cars are to be sold that do not get a prolonged road-test. In many cars the gears have fair accuracy of spacing and tooth form, but contain a roughness of the teeth that requires some running to overcome.

Mr. Herrmann asked me to tell how we get a quiet cluster-gear with the four gears in one piece. I cannot say that we have any special way of doing it. We make them as carefully as we can. We are using high-speed Fellows gear-shaping machine cutters equipped with steady rests for the work arbors. One thing we have done; we have a large driving gear on one end. We put all the backlash into the large gear. On the other end we have a small reverse gear. We cut that to standard size and put all the backlash in the mating gear, because we all know that we get more tooth-form change by adding backlash to a small gear than to a large gear. We hold the forms somewhat closer by that particular method. We found something rather interesting in burnishing a cluster gear. We have three medium-size gears and a small reverse gear on the end. It seemed reasonable to suppose that we could not properly burnish the reverse gear with almost the entire weight of the cluster gear overhanging. We felt that we should have to rig up something to take care of that weight. We found, however, that when we put a bar about 18 to 20 in. long in the hole we could not observe any eccentric motion; this proved to us that we were getting pretty good contact on the teeth during burnishing.

We all have our gear troubles. Anyone who makes gears will have trouble. We felt that we should have somewhat of a premium on the trouble, for, in the ordinary sliding-gear transmission, not so many gears are in constant mesh as in our traffic transmission. All our gears are in constant mesh and there are 10 gears in the transmission. One point, however, is to our advantage; we are able to use full teeth instead of stub and, consequently, avoid some interference at the tops of the teeth. We certainly need this help as we must have quiet gears to get a quiet job.

The only way we know of for making gears quiet is to begin at the bottom, take exhaustive care from the annealing of the forging, through the blanking and the gear cutting and the burnishing.

TRANSPORTATION IN NEW ENGLAND

THREE groups of agencies in New England are engaged in transportation of people and commodities; (*a*) steam and electric rail-lines, (*b*) boat lines and (*c*) highway transportation companies. Highway transportation of freight and passengers is increasing in volume each year. Its development has been so rapid and the information as to its movement is so meager that it is extremely difficult to lay down any definite principles as to the economic sphere of motor-trucking companies engaged in the highway transportation of freight. The following is a tentative outline of the economic fields of motor-truck transportation as a correlated part of our transportation system:

(1) Organized urban motor-truck transportation in congested terminal areas consisting of motor-truck terminal to terminal freight transfers as well as pick-up and delivery service

(2) The organization of motor-truck freight service to supplement and extend existing rail and water transportation agencies

(3) The short-haul transportation of freight, probably not to exceed 30 miles

(4) Motor-truck transportation of a limited number of special commodities in the long-haul zone in which delivery time, the character of the goods transported or the demands of the industry or trade indicate the desirability of motor-truck transportation

Carefully organized and efficiently operated motor-trucking companies in the first field, if assured of railroad and steamship cooperation, will materially speed-up freight movement, decrease the volume of freight warehoused, reduce the cost of moving freight through terminals and expedite the rail delivery time of less-than-carload freight.

The second type of service mentioned is especially desirable in the development of new areas or localities with insufficient transportation facilities and will make available additional tonnage for movement by rail or water. This is a non-competitive service extending and supplementing rail and water agencies.

The differences in the density of population in the different areas, the distance between cities and areas of production and distribution, the prevailing type of production and the type of rail or water transportation available may decrease or increase the zone of the short haul mentioned under (3).—From an article by J. G. McKay in the *Engineering News-Record*.

"GROWTH" OF ALUMINUM PISTONS

THE reason for the popular belief that aluminum pistons grow may be found in the fact that accurate measurements of the changes of dimension in the castings have very rarely been made, while the general observations that led to the belief appear to have been made upon pistons machined directly from unannealed castings and put into the engine without any further treatment whatsoever. It is worthwhile to consider in what way this fact affects the observations.

All aluminum pistons are cast in comparatively thin sections, and therefore cool fairly rapidly. In addition, very many are cast in chill-molds that certainly hasten the rate of cooling. Altogether, it may therefore be taken that a piston is a fairly quickly cooled casting. It is further to be noted that within the average piston casting a moderate variation of section is found, the piston-pin bosses and even the crown being generally of considerably greater thickness than the skirt. This means that the normal shrinkage which occurs during casting will be different in the various parts of the piston. Apart from any other possible causes, the chilling action and the different shrinkages in the casting undoubtedly set up a state of considerable stress between the different parts. This stress is always likely to diminish if opportunity serves. If it does diminish, a change of *shape but not of density* in the casting may result. Two prime opportunities are afforded for the alteration of the stresses. The first occurs during the machining of the casting. As a rule this operation only partially relieves the stresses and in some instances may actually increase them in certain portions of the article. The second occasion on which the stresses may be affected is when the castings are heated, which increases the ease with which they may rearrange themselves internally. With an unannealed casting, this heating will first occur when the machined castings are run in the engine. Naturally, the metals will then tend to set themselves so as to dissipate the stresses under which they are constrained, and this alteration of the stress distribution may easily result in a change of shape. Undoubtedly, what has been described happens to many pistons when they are introduced into an engine and put into service. What happens is not that the pistons *grow* but that they *warp*, an entirely different thing.—From a paper by Leslie Aitchison, presented at meeting of the Institution of Automobile Engineers.

REPARATIONS PAYMENTS

THE Reparations Commission made public its official figures of the actual reparations payments made by Germany from the date of the execution of the Treaty of Versailles to Dec. 31, 1923. According to these figures, the total payments in cash and kind made by Germany in the period stated were equivalent to 8,411,000,000 gold marks. Of this sum 1,903,000,000 gold marks was in cash, the remainder being made up of deliveries in kind or ceded property. The unpaid costs of the armies of occupation and of the commissions of control amount to 2,613,000,000 gold marks, not including the American Army costs of 1,071,000,000 marks.

The Reparations Commission's figures show that Belgium, both in cash and in deliveries in kind, received the equivalent of 1,445,000,000 gold marks net, after the deduction of the cost of maintaining her army of occupation and reimbursement for coal advances to Germany. The larger part of the payments to Belgium were in cash, amounting to more than 1,000,000,000 gold marks.

France has received 1,800,000,000 gold marks, mostly in deliveries in kind, but the net balance remaining for application on reparations account proper, after deducting the costs of the occupation troops and reimbursement for coal advances to Germany, is only 189,000,000 gold marks.

Great Britain received 1,318,882,000 gold marks; Italy 397,932,000; Japan 68,368,000; Serbia 262,500,000; Greece 20,574,000; Poland 15,120,000; Rumania 33,914,000; Czechoslovakia 23,153,000; and Portugal 14,855,000.—*Economic World*.

HORSE AND MOTOR-TRUCK HAULAGE

THE mechanical-traction millenium has not yet arrived and, while in military movements the mechanical arts are likely to be of ever-increasing importance, in more peaceful pursuits the horse will yet be found to have an economical field. Congested places show a surprising preponderance of heavy horse-drawn vehicles. The reason is not far to seek. Broadly speaking, the heavy traffic at a point like Covent Garden, London, can be divided into bulk traffic from outlying market gardens, and that to and from docks and railroads. The remainder consists practically of the vehicles of retailers and the like from the suburbs. Of the two heavy classes a large proportion of the first class is efficiently done by motor vehicles. For the second horse haulage is still preferred, for which at least two good reasons can be advanced. The less important is indisputable and can be quickly dismissed. In narrow streets and confined areas, sometimes to be found in the neighborhood of markets and often in the freight stations and warehouses of the railroads built before the days of the motor truck, the superior maneuvering power of the horse vehicle is a very valuable factor. Here the speed of the motor truck as a contributory cause to the elimination of congestion does not enter. Movement at the best is slow and well within the power of the horse, while the turning circle of the horse vehicle is such that, as the saying goes, it can make rings round the big motor truck.

The more important reason, from the owner's point of view, has its root in another entirely different consideration. It is due to the bearing that the total annual cost has upon the standing time. Just as in railroad transport the actual time of movement of a carload of freight is a very small part of the whole time occupied between two successive loadings, so, as every successful road transporter is aware, the actual time occupied in cartage is generally very low compared with the total time spent in road hauler's work. The special class of market traffic to which we have referred above is an extreme one. The distances are relatively short; the delays at the markets abnormally long. Under these circumstances the more costly motor truck cannot in these days compete unless for some reason prices in connection with horse haulage are very high. The superficially attractive idea that an idle motor truck is not all the time "eating its head off" is discounted by the much higher standing charges that have to be carried.

The costs used in working out examples were £250 per annum for a single-horse team; £350 per annum for a two-horse team; the same for a 1-ton gasoline motor truck; £460 for a 2-ton motor truck and the same for a 3-ton motor truck. With these figures, and comparing a horse and 2-ton motor truck, carting 2 tons of traffic, with calls, it was shown that with loads involving six calls, the horse can compete with the motor truck up to 7 miles, assuming return loading, each additional 5-min. stop adding 0.4 miles to the economical equality of the horse and the motor truck. For two such vehicles, carting to one destination, the two are on equality up to 5 miles, beyond which the motor truck has the advantage. Again working to one destination with a full load, a trotting horse can hold its own against a 1-ton motor truck up to 4 miles, but for the same conditions of full load to one consignee a 3-ton motor truck becomes as cheap as a two-horse team at 2 miles and over. If, compared with the trotting horse, it is only possible to employ a 2-ton motor truck for the 30-cwt. load, the horse has the advantage within the range of its powers.

In parcel delivery work, taking the case of a 1-ton load delivered to 80 consignees, the horse, within its physical capabilities, can work up to any distance more economically than the 1-ton motor truck. On heavier work, such as 2 tons of freight delivered to four consignees, the motor truck becomes economical at 6¼ miles and over, but additional delays increase the distance and an extra 30 min. would raise the limit for the horse to 8½ miles.

These figures are given merely to illustrate that the bearing which delays have on operation is unquestionable.—*Engineering.*

WAGES OF AMERICAN WORKERS FOR 80 YEARS

THE accompanying table, taken from *The Protectionist*, Boston, gives the average number, the weekly working period, the average hourly earnings and the average weekly earnings of employes of Cheney Bros., silk manufacturers, of Manchester, Conn., at various intervals throughout the past 80 years.

SILK MILL WORKERS' EARNINGS FOR THE PAST 80 YEARS

Period	Average Number of Employes	Weekly Working Period, Hr.	Average Earnings Per Hour	Average Earnings Per Week
1843	18	72	$0.0428	$3.08
1848	86	72	0.0720	5.18
1856	78	72	0.0780	5.62
1860	135	72	0.0810	5.80
1863	131	60	0.1070	6.42
1870	406	60	0.1490	8.94
1880	1,165	60	0.1320	7.92
1890	1,786	60	0.1510	9.06
1900	2,675	60	0.1560	9.36
1910	3,965	60	0.1790	10.74
1914	4,307	55	0.2040	11.22
1920	4,670	48	0.6080[a]	21.15[a]
1923 (July)	4,414	48	0.6080	29.18

[a] The peak of hourly earnings was reached in the last quarter of 1920, but owing to the plant being operated on 34.8 hr. per week, full-time weekly earnings were not obtained by the employes.

Throughout this 80-year period the trend of wages has been upward, and only two recessions of any magnitude have taken place; one recession occurred after the Civil War, between 1870 and 1880, which amounted to approximately 11 per cent and was occasioned by the resumption of specie payments; the other recession occurred after the World War in 1921, amounting to approximately 14 per cent, which was occasioned by the depression in business that took place in 1921 and 1922.

The upward trend in wages has been due principally to the two war periods already mentioned. The period of 27 years between 1843 and 1870, which included the Civil War, showed an advance of 248 per cent in the average hourly earnings, or an average yearly increase of 9.18 per cent. The 30-year period between 1870 and 1900 obtained only a 4.7-per cent increase in earnings, or a yearly rate of increase of about one-sixth of 1 per cent. The 23-year period between 1900 and 1923, which included the World War, produced an advance of 290 per cent in earnings, or a yearly increase rate of 12.61 per cent. The three periods into which the last 80 years have been divided roughly represent nearly three generations in time, and if the future of wages bears any relation to the conditions that have prevailed in the past 80 years, then we may expect present wages to be maintained, but not materially increased for nearly another generation in time.—*Economic World.*

Applicants *for* Membership

The applications for membership received between March 15 and April 15, 1924, are given below. The members of the Society are urged to send any pertinent information with regard to those listed which the Council should have for consideration prior to their election. It is requested that such communications from members be sent promptly.

ARNOLD, B. W., manager of motorcoach department, Chicago, North Shore & Milwaukee Railroad Co., *Chicago.*

BALL, HAROLD APPLETON, draftsman, Autocar Co., *Ardmore, Pa.*

BARNARD, JOHN HALL, Engineers Club, 32 West 40th Street, *New York City.*

BRACE, WILLIAM R., factory manager, J. W. Murray Mfg. Co., *Elizabeth, N. J.*

BRITT, BENJAMIN H., shop superintendent, Ward Baking Co., *New York City.*

BROWN, H. FLETCHER, student, Iowa State College, *Ames, Iowa.*

BUTTERFIELD, O. A., chief of experimental department, Nichols & Shepard Co., *Battle Creek, Mich.*

CHARLES, MILTON C., general manager, Leo B. Pumpian, *New York City.*

CHATER, JOHN A., engineer, Elite Mfg. Co., *Ashland, Ohio.*

CROOKSTON, JAMES J., cadet engineer, Waukesha Motor Co., *Waukesha, Wis.*

DANIEL, JULIAN TURK, student, Georgia School of Technology, *Atlanta, Ga.*

DAVIS, CHASE, 1327 Lenox Avenue, *Detroit.*

DE LANGE, KAREL, draftsman, Graham Bros., *Evansville, Ind.*

DONOHOUE, S. E., draftsman, Powell Power Co., *Cleveland, Ohio.*

FEHLBERG, CHESTER H., layout draftsman, Pierce-Arrow Motor Car Co., *Buffalo.*

FLOWERS, HERBERT B., president, New Orleans Public Service Inc., *New Orleans.*

GAGE, RUSSELL, acting assistant service manager, Ford Motor Co. of Canada, Ltd., *Ford, Ont., Canada.*

GRAVES, W. H., chief metallurgist, Packard Motor Car Co., *Detroit.*

HARMER, F. E., consulting engineer, Raydale, *Chatburn, Lancashire, England.*

HARRIS, SIDNEY J., truck sales manager, Smith & Gregory, *New York City.*

HECKLER, L. C., superintendent, Buda Co., *Harvey, Ill.*

HENRY, JOHN W., mechanical expert, Westinghouse Air Brake Co., *City of Washington.*

HOWARD, WALTER S., sales and service engineer, Muncie Foundry & Machine Co., *Muncie, Ind.*

HUGHES, JAMES J., service manager, Mack-International Motor Truck Corporation, *Pittsburgh.*

HUMBERT, R. L., engineer, Kohler Co., *Kohler, Wis.*

JOHNSON, HARLEY A., assistant to the general manager, Chicago, North Shore & Milwaukee Railroad Co., *Chicago.*

KIMBALL, LEO B., research assistant, Mason Laboratory, Yale University, *New Haven, Conn.*

KOCHER, ERNEST A., inspector and tester, Gruss Air Spring Co., *San Francisco.*

KULL, PAUL A., technical business executive and sales agent, National Rubber Filler Co., *Midlothian, Tex.*

LANDIS, ROBERT B., electric test man, Autocar Co., *Ardmore, Pa.*

LAVERS, ALBERT W., chief draftsman, Minneapolis Steel & Machinery Co., *Minneapolis.*

LAWTON, HOWARD B., general manager, Clark Cutter Co., *Detroit.*

LONG, MERVYN HOWARD, superintendent, Hemphills Auto & Gas Tractor Schools, *Toronto, Ont., Canada.*

LOUGHEAD, MALCOLM, Four Wheel Hydraulic Brake Co., *Detroit.*

LUCAS, ANTHONY F. G., development engineer, 2300 Wyoming Avenue, *City of Washington.*

MCKEE, L. Z., manager of sales, Canedy-Otto Mfg. Co., *Chicago Heights, Ill.*

MADILL, GEORGE J., owner, Motor Car Electric Service, *Highland Park, Ill.*

MAJNERI, LUDWIG, engineer, Curtiss Aeroplane & Motor Co., *Buffalo.*

MARSHALL, RAYMOND W., president, Transit Equipment Co., *New York City.*

MATTHEWS, RALPH R., manager of lubrication sales division, Roxana Petroleum Corporation, *St. Louis.*

MERRILL, HARRY C., draftsman, 12 Bellevue Street, *Lowell, Mass.*

MILLIKEN, S. LESTER, draftsman, Locomobile Co., *Bridgeport, Conn.*

MISELL, NEWTON B., sales manager, Asbestos Textile Co., *New York City.*

MONK, LOUIS P., assistant manager, Harvey Spring & Forging Co., *Racine, Wis.*

NADIN, THOMAS, engineer, Rolls-Royce of America, Inc., *Springfield, Mass.*

NEUWOEHNER, HIRAM, assistant purchasing agent, Moon Motor Car Co., *St. Louis.*

NIPPS, L. H., student, Kansas State Agricultural College, *Manhattan, Kan.*

PATZIG, GURT H. M., mechanical draftsman, Bear Tractors, Inc., *New York City.*

PIERCE, WINSLOW S., JR., chief engineer, Ringless Piston Co., *Hoboken, N. J.*

ROBERTS, ADRIAN SCHARFF, student, Stevens Institute of Technology, *Hoboken, N. J.*

ROWAN, FRANK E., service department, Nash Motors Co., *Kenosha, Wis.*

SECOR, JOHN A., consulting engineer, Advance-Rumely Co., *LaPorte, Ind.*

SEELINGER, H. D., bus equipment engineer, Milwaukee Electric Railway & Light Co., *Milwaukee.*

SIDDONS, GEORGE F., service engineer, Timken-Detroit Axle Co., *Detroit.*

SKINNER, CHARLES R., JR., manager, New York Edison Co., *New York City.*

SMITH, NORMAN J., general superintendent of transportation, Consumers Co., *Chicago.*

SNOW, EDWARD JAMES, manager, commercial car division, Vacuum Oil Co., *New York City.*

THOMPSON, F. D., lubrication engineer, Vacuum Oil Co., *Boston.*

TOMPKINS, STEPHEN B., service manager, Mack-International Motor Truck Corporation, *Chicago.*

VOSE, EDWIN W., engineer, Room 511, Barristers Hall, *Boston.*

WEBB, S. A., 222 Ridgewood Avenue, *Orlando, Fla.*

WISHART, T. D., chief designer, Crossley Motors Ltd., *Gorton, Manchester, England.*

WOOD, EDWIN C., automotive engineer, Pacific Gas & Electric Co., *San Francisco.*

ZUCK, HARRY EDWIN, student, University of Michigan, *Ann Arbor Mich.*

Applicants *Qualified*

The following applicants have qualified for admission to the Society between March 10 and April 10, 1924. The various grades of membership are indicated by (M) Member; (A) Associate Member; (J) Junior; (Aff) Affiliate; (S M) Service Member; (F M) Foreign Member; (E S) Enrolled Student.

AKRON-SELLE CO. (Aff) *Akron, Ohio.*
Representatives:
Hamlin, E. W., secretary.
Hower, John B., vice-president and general manager.

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